ARCHIVES OF SURGERY

VOLUME 53 SEPTEMBER 1946 NUMBER 3

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PATHOLOGIC INTERVERTEBRAL DISK AND ITS CONSEQUENCES

A Contribution to the Cause and Treatment of Chronic Pain Low in the Back and to the Subject of Herniating Intervertebral Disk

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I. INTRODUCTION

Some time ago I studied with Dr. Arthur Steindler, of Iowa City, the problem of chronic pain low in the back in relation to the syndrome of herniating intervertebral disk. We made an attempt to differentiate what we called true herniating, or ruptured, disk from pain low in the back with "reflex" pain. Two observations were outstanding. First, a patient without herniation of the intervertebral disk seldom complained of pain below the knee, although he frequently complained of pain down the thigh to the knee. Second, as Steindler pointed out, it was possible to find points of maximum tenderness about the sacrum and gluteal regions in such a patient which if made anesthetic with procaine hydrochloride would completely relieve the patient of his discomfort temporarily. A patient with a herniating, or ruptured, disk causing compression of a nerve root would definitely not experience relief

of sciatic pain by such an injection of procaine hydrochloride and for obvious reasons, viz., the source of the pain in the nerve root was untouched by the procaine hydrochloride. Hence, Steindler introduced his test with procaine hydrochloride as a means of differentiation between chronic pain low in the back with, perhaps, "reflex" pain down the thigh and herniating disk with "radiating" pain down the sciatic distribution. The term "reflex" is used to imply that the referred pain is not due to compression of a nerve root, while "radiating" implies that it is due to compression of the nerve root. The results of these studies were published by Steindler and Luck,[1] Steindler [2] and Hyndman, Steindler and Wolkin.[3] At that time we were content with recognizing that a patient with chronic pain low in the back and perhaps reflex pain who was temporarily relieved by the injections of procaine hydrochloride (positive results in the test with procaine hydrochloride) did not have a herniating disk and therefore was not a candidate for operation. In such a case we made a diagnosis of "myofascial syndrome," which implies a strain or sprain of the ligaments and of the tendinomuscular structures about the lumbosacral and sacropelvic regions. This would be cause for the pain low in the back and the reflex pain in the thigh that may accompany it. Such patients were segregated from those who presented definite syndromes of herniating disk, and they were put through the ritual of conservative treatment, including rest in bed, with traction to one or both lower extremities, belts,[4] corsets, braces and, as the court of last appeal, tibial bone grafts [5] in an attempt to stabilize the lumbosacral joint.

Definition.—It is appropriate at this point to define degenerating and herniating disks, so that references to the two entities throughout the paper might be clearly understood. A degenerating intervertebral disk is one in which the nucleus pulposus and the annulus fibrosus are undergoing disintegration. While the gross pathologic changes of a degener-

1. Steindler, A., and Luck, J. V.: Differential Diagnosis of Pain Low in the Back; Allocation of Source of Pain by Procaine Hydrochloride Method, J. A. M. A. **110**:106-113 (Jan. 8) 1938.

2. Steindler, A.: The Interpretation of Sciatic Radiation and the Syndrome of Low Back Pain, J. Bone & Joint Surg. **22**:28-34 (Jan.) 1940.

3. Hyndman, O. R.; Steindler, A., and Wolkin, J.: Herniated Intervertebral Disk: A Study of the Iodized Oil Column; the Procaine Test in Differential Diagnosis from Reflected Sciatic Pain, J. A. M. A. **121**:390-401 (Feb. 6) 1943.

4. The narrow so-called sacroiliac belt can hardly be more than psychologic therapy in the treatment of the symptoms for which it is prescribed. If any attempt is made by external appliance partially to even stabilize the lumbosacral joint, a tall corset with rigid stays or, better, a steel spring back brace is required. Many corsets are efficacious only in the support of a protuding abdomen.

5. The usual bone graft is too short. Some of them do not "take" and, hence, serve no purpose at all. In order to obtain a successful "take," or fusion, the patient should be immobilized in a body cast for at least eight weeks or more. On the whole, the results of bone grafting have been unsatisfactory.

ating disk are obvious to inspection, the cause and nature of the pathologic changes are not yet so clearly understood. Herniation is only an advanced stage of degeneration, but when the term "degenerating" is used it is implied that there is as yet no bulge, or herniation, that would cause pinching or compression of an adjacent nerve root. The term "degenerating" rather than "degenerated" is used because the process, however slow, is probably continuous and progressive.

Herniating disk is the term used to designate a disk that, because of weakened capsule or annulus, bulges, partly or entirely, into the spinal canal beyond physiologic limits. The bulge, or herniation, compresses a nerve root against the adjacent ligamentum flavum, giving rise to symptoms and signs appropriate to compression of the nerve root. The annulus may rupture and the nucleus extrude through it. In the interests of specialized and descriptive nomenclature such types should be specified, but for all practical purposes these types, which are discussed under terminology, may be encompassed in the broader term, "herniating" disk. Here again the term "herniating" is preferred to "herniated," in order to imply a continuous process. When a part or all of the nucleus pulposus is completely sequestrated and extruded, the process may have likely reached an end stage and, in this case, could be more properly termed herniated disk. In any case, when the term herniating disk is used throughout this paper, it is intended that it be synonymous in connotation with various terms that have appeared in the literature, viz., protruded disk, slipped disk, ruptured disk or fractured disk.

Throughout this presentation considerations relating to the degenerating and the herniating disk must run concomitantly, because the two are only different aspects of the same pathologic process and the symptom complexes they provoke are closely associated and often combined. The consideration of the two as being different entities is justified only because of the fact that they do provoke distinctly different syndromes, namely, chronic pain low in the back and pain from compression of a root. Since the common location of pathologic changes in disks is being considered, the fourth and fifth lumbar disks, the pain from compression of the roots specifically resolves itself into the well known sciatica or radiating pain in the sciatic distribution. Criticism may be proffered for separation of this pathologic change in disks into two distinct entities from a pathologic standpoint, but the separation is justified because each is associated with its own characteristic syndrome. The two syndromes may exist each to the exclusion of the other, or they may be combined.

II. CAUSE OF CHRONIC PAIN LOW IN THE BACK

A number of facts and thoughts presented themselves which led to the conclusion that most chronic pains low in the back are due to soft or degenerating intervertebral disks.

1. Seventy-five per cent of the patients in my experience who have proved herniating, or ruptured, disks give histories of chronic pain low in the back for some time before they experienced sciatic radiation or the symptoms and signs of compression of a nerve root. Some patients do indeed give histories of sudden and spontaneous onset of sciatic pain due to compression of a root and deny absolutely the preexistence of pain low in the back. At operation, most of these patients present laterally placed herniations of only small portions of the nucleus pulposus. The small sequestrated portion is seated in a definite small pocket, which, when cleanly and thoroughly curetted out, proves to have a hard, firm and glistening wall. The remainder of the disk is not soft but has a normal firmness and integrity. I feel that this finding is significant when correlated with the absence of chronic pain low in the back in the history. Such patients present the syndrome of only compression of a root from the beginning. The operative relief of pain is immediate and the results most satisfactory because the syndrome is not complicated by the effects of a totally degenerating disk—effects which are outlined further in this paper.

Three of the patients in my total experience who gave histories of chronic pain low in the back preceding the onset of sciatic radiation stated that the pain low in the back disappeared in time after the sciatic radiation developed. Although only a conjecture, this might indicate that after the nucleus was spontaneously extruded a firm fixation between the adjacent vertebrae could be established by the development of a fibrocartilaginous scar, thus remedying the cause of the pain low in the back. Nature, in this respect, attains the result that the surgeon seeks by removal of the pathologic nucleus. The extruded nucleus, however, provokes a new type of pain for the patient—that due to compression of a nerve root. Compression of a nerve root alone does not cause the type of chronic pain low in the back under discussion. This is attested to by the patients who have sciatic radiation without ever having experienced pain low in the back.[6] Chronic pain low in the back and sciatic radiation (or pain in a nerve root) are distinctly separate clinical entities and have entirely different explanations, although the two are attributable to different aspects of the same pathologic process.

2. A study of the pathologic and histologic changes of the intervertebral disks below the fourth and fifth lumbar disks, and sometimes both, in a patient with the type of chronic pain low in the back under consideration is convincing and is elaborated under the section devoted to pathology.

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6. In cases of benign tumor (i. e., perineural fibroblastoma) involving a root or roots of the cauda equina, the patient will experience radiating pain in a distribution corresponding to the involved roots, but pain low in the back of the type discussed in this paper is not a feature of the syndrome.

3. If the disk below the fourth or fifth lumbar spaces is soft and degenerating there will be an instability of the lumbar or the lumbosacral joint—an instability that orthopedists must have recognized years ago and which they sought to remedy by bone graft. Such an instability occasions an undue stress and strain on the perispinal ligaments and muscles and is the probable cause for the "myofascial syndrome," or pain low in the back. Although much effort has been made to demonstrate nerve fibers in the disk, I do not believe that the disk itself is the source of pain, or else, in keeping with this thesis, Steindler's test with procaine hydrochloride would never give positive results. Jung and Brunschwig,[7] after careful study, found no evidence of nerve fibers in the intervertebral disks. They found nerve fibers only in the anterior and lateral longitudinal ligaments. Keyes and Compere[8] remarked that, therefore, trauma or disease affecting the intervertebral disks can produce subjective symptoms only in proportion to the degree in which the adjacent structures are involved. Steindler's observations on the test with procaine hydrochloride provide a capital contribution to the problem of pain low in the back because they throw light on its true nature and lead one to the primary cause.

I should not presume to imply that a degenerating disk is the *sine qua non* for every case of strain or sprain low in the back. The object of this paper is to propose that a degenerating disk is the one commonest primary cause for the type of chronic pain low in the back to be described.

III. SYNDROME OF CHRONIC PAIN LOW IN THE BACK DUE TO DEGENERATING INTERVERTEBRAL DISK

The symptoms under this caption are strikingly consistent. The significant ones are as follows:

1. Chronic pain low in the back has usually existed for years. The patient consistently locates this pain in the lumbosacral region or the upper aspect of the sacrum. Often the maximal pain will be in the region of the sacroiliac joint[9] or located at a point about midway between the

7. Jung, A., and Brunschwig, A.: Recherches histologiques sur l'innervation des articulations des corps vertébraux, Presse méd. **40**:315-317 (Feb. 27) 1932.

8. Keyes, D. C., and Compere, E. L.: The Normal and Pathological Physiology of the Nucleus Pulposus of the Intervertebral Disc: An Anatomical, Clinical and Experimental Study, J. Bone & Joint Surg. **14**:897-938 (Oct.) 1932. (Note—These authors give an excellent bibliography.)

9. This common location of the pain makes it understandable that for so long the syndrome under discussion was thought to be due to a "sacroiliac strain," in spite of the totally normal roentgenologic findings and even absent ankle reflex (in cases of herniating disk). Strain of the sacroiliac joint as a diagnostic entity *sui generis* must, for the most part, be a mistaken entity and the diagnosis without foundation. Although the diagnosis is still commonly made, it must surely in time become obsolete.

sacroiliac joint and the greater trochanter of the femur. The significant fact is that the pain is not referred higher.[10]

2. This chronic pain low in the back may be associated with reflex pain down the posterior aspect of the thigh. Such reflex pain does not commonly extend below the knee and ordinarily is not so specifically localized to the sciatic nerve as is that which is due to compression of the nerve root. It is not uncommon for the reflex pain to be bilateral or to shift from one thigh to the other or even at times to be referred to the lateral or the anterior aspect of the thigh.

3. The episodes of pain are periodic and usually become maximal the day following some work such as shoveling snow or working in a garden. The following morning the patient complains of unusual stiffness and pain low in the back and finds it difficult to get out of bed. A common statement is that he has to crawl slowly out of bed.

Soft mattresses, which cause the patient to maintain a somewhat flexed posture in bed, are especially provocative of pain low in the back for these patients. The spinal axis at the lumbar or the lumbosacral joint is weak, and the flexed posture maintains a perpetual strain on the perispinal ligaments and erector spinae muscles, which results in pain and stiffness low in the back. Many of the patients have discovered this for themselves and have found that they fare much better by sleeping on the floor. This is understandable when one realizes that the type of backache under consideration is due to strain on the ligaments and muscles and is comparable to the pain of a stiff arthritic knee. After the patient maintains a fixed posture for a time, such as lying in bed or sitting in a chair or sitting in a theater, he experiences stiffness and pain low in the back when he attempts to straighten up. These patients find it more difficult to stay in one position than to shift or to keep moving. They are particularly "poor sitters."

4. Exaggeration of the pain on coughing or sneezing is denied or is minimal because of the absence of compression of a nerve root and the attending inflammation of the root that is associated with herniating disk. The patient does not experience various forms of paresthesia of a leg or foot for the same reason—absence of compression of a root.

On examination of the patient the various signs that one tests for in respect to herniating disk are not outstanding. Bending of the back is limited and causes pain referred to the lumbosacral joint. Spasm of the erector spinae muscles, painful straight leg raising and tenderness to hard

10. Strictly postural backache (in otherwise normal backs) is referred to the upper part of the lumbar region, the loins and the lower ribs. It can be no better depicted than in the well known advertisements for medicines for renal disease. Such pain seldom has any relation to the kidneys but is a postural backache and is commonly induced by the half reclining posture on modern davenports and soft mattresses.

pressure on the fourth and fifth lumbar spines may be present but are not nearly so outstanding as in the case of herniating disk. One does not find hypalgesias in the distribution of the fifth lumbar and first sacral roots, and there is no absence or diminution of the achilles tendon reflexes.

Before the diagnostic features of degenerating intervertebral disk and herniating intervertebral disk are contrasted and compared, it is well to review the symptoms and signs of the latter as they are known to be at the present time.

IV. SYNDROME OF HERNIATING, OR RUPTURED, INTERVERTEBRAL DISK

Since the causal factor of recurring or persistent sciatic pain was pointed out in 1934 [11] as a common entity, a great deal of study has been devoted to the syndrome of herniating intervertebral disk. The discovery of this syndrome is one of the important advances of the century and provides a solution to a serious problem of relatively high incidence. Thousands of patients have been operated on, and many reports have been made. In the earlier days, caution led to the visualization of the herniating disk by myelography with iodized poppyseed oil and air and to prolonged conservative treatment before operation was resorted to. Time and experience have led to the conclusion that chronicity, unilaterality and typical radiation of sciatic pain to a leg or ankle means herniating intervertebral disk until otherwise proved. The diagnosis has proved to be accurate in 90 to 95 per cent of cases—as high an accuracy as in the diagnosis of any nonvisualized pathologic entity. The syndrome of herniating intervertebral disk is predominantly that of pain in a nerve root because the protruding portion of the disk compresses a nerve root against the ligamentum flavum adjacent to it (see figure 1). Because 90 to 98 per cent of the pathologic disks are below the fourth or fifth lumbar vertebra, the important and usual features in the history are as follows.

Chronic pain low in the back is referred to the level of the sacrum or lumbosacral joint and is associated with pain in the region of the sciatic notch, radiating down the posterior aspect of the thigh and to the calf or lateral aspect of the leg and often to the ankle, heel, entire foot or either side of the foot. About 25 per cent of the patients deny the presence of pain low in the back and describe only sciatic pain. A small percentage of patients experience sciatic pain on both sides, and in these patients the pain is usually unilateral for some time before becoming bilateral. This is an indication that the herniation has become extensive enough to compress the corresponding roots on each side of the spinal

11. Mixter, W. J., and Barr, J. S.: Rupture of the Intervertebral Disk with Involvement of Spinal Canal, New England J. Med. **211**:210-215 (Aug. 2) 1934.

canal. One of the notable features, however, concerning herniating disks is that the herniation and hence the sciatic pain are so commonly unilateral and associated with no pain whatever or at any time in the opposite extremity.

Remissions of pain are characteristic. The interval between attacks as well as the duration of the attack varies greatly. As time goes on, the attacks become more frequent and the patient comes to fear the next inevitable attack, which may be precipitated by a trivial strain or come about spontaneously. Probably one of the reasons the patient recovers from an attack is that everything is done to place the lesion at rest. Spasm of the erector spinae muscles and curvature of the spine, with tilting of the pelvis, develop to splint the spine and favor the lesion.

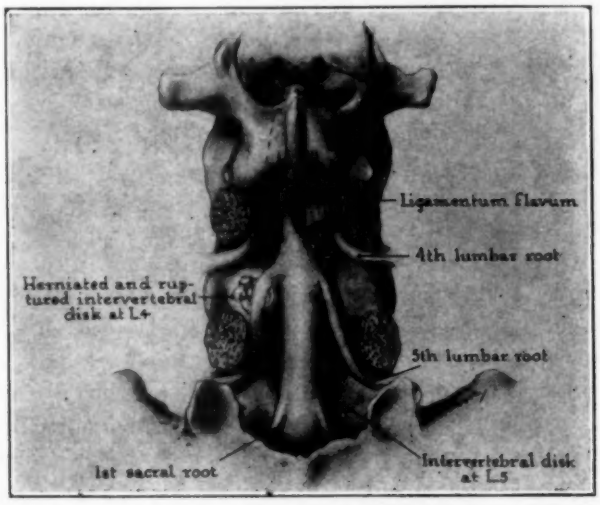

Fig. 1.—Drawing which illustrates the usual type and location of herniating intervertebral disk. The herniation of a mass of extruded nucleus compresses the overlying nerve root against the closely investing and unyielding ligamentum flavum. The ruptured herniation and extruded nuclear material shown here are of the fourth lumbar disk. Those occurring at the fourth and fifth disks are of about equal incidence.

The patient makes as few unfavorable movements as possible and may even take to bed for a few days and thus put the lesion at rest. Between recurrences of acute pain the patient may feel well or may be conscious of a residual pain of varying degree in the hip or back of the leg.

There is one occasion on which the patient takes to bed and ordinarily remains bedridden until relieved by operation. This occurs when the sequestrated nucleus pulposus is suddenly extruded into the spinal canal. At operation the surgeon finds the nucleus in the canal, severely displacing the adjacent nerve root, and the nucleus often can be pulled away in one piece.

Coughing and sneezing almost invariably aggravate the pain of herniating disk. Patients often state that they have to grab hold of something when they sneeze, because pain is so terrific. This is undoubtedly due to the effect or impingement of the spinal fluid "pressure wave" on the hypersensitive, inflamed nerve root.

Paresthesia in some form is almost invariably experienced by persons with herniating disks. It is significant evidence of involvement (in this case, compression) of the sensory component of a nerve root. The patient most commonly describes or recognizes the paresthesia as a "sleepy" feeling in the leg or foot. Other interpretations are "numbness," "pins and needles feeling" and sensation of "coldness."

Patients with degenerating disks which have not herniated and those with herniating disks often have difficulty in resting at night, because of discomfort. Both classes of patients also often complain of stiff and painful backs when getting out of bed in the morning. However, it is worth repeating that there is a consistent difference in the two classes in respect to moderate activity as the day is begun. Those without herniation of the disk appreciate some relief from the pain low in the back as they "limber up," while those with herniating disks and their resulting pain from compression of the roots experience exaggeration of pain with activity.

In taking the history one should always inquire about control of the bowels and bladder in order that conditions other than herniating disk might not be overlooked, such as tumor of the cauda equina. Simple herniating disk does not affect bowel and bladder control (see section on rare and unusual cases).

The Examination.—The patient should unquestionably be subjected to a general examination before being operated on for herniating disk. However, he is often referred to a neurologist or neurologic surgeon for the express purpose of determining whether the diagnosis is herniating disk or not. In this respect I have found ten features concerning the examination that I feel are significant.

Tests Made with Patients Standing:

1. The lordotic curvature of the lumbar portion of the spine. The lordotic curvature of the lumbar portion of the spine is usually flattened. This can be determined by inspection and by a lateral roentgenogram of the lumbar portion of the spine. The patient should be stripped except possibly for a loincloth and asked to stand in his natural posture, with heels together. It is striking how commonly persons with herniating disks have flat backs and how uncommonly they present pronounced lordosis of the lumbar part of the spine. How much of this flattening is due to muscle spasm and how much is natural for the patient is difficult to say. However, one should be wary of patients with pronounced lordosis. I have operated on 3 patients (all women) who presented pronounced

lordosis. There was sufficient evidence on which to base a suspicion of herniating disk, but all 3 patients proved not to have such at operation. The causal factor for the pain in these patients is not yet clear, but it is interesting that extensive decompression of the fifth lumbar and first sacral roots on both sides was rewarded by considerable relief from symptoms. By decompression is meant extensive removal of the ligamenta flava, especially that which invests the lateral walls of the spinal canal and the proximal aspect of the intervertebral canals. This is combined with partial unroofing and widening of the intervertebral canals.

2. Physiologic scoliosis. The lumbar portion of the spine is often curved in a lateral direction to some extent. The curvature can be discerned by inspection of the patient's back as he stands. It is also evident in the anteroposterior roentgenogram of the lumbosacral portion of the spine. The curvature is a result of muscle spasm and may be either toward or, more often, away from the side of the sciatic pain. Tilting of the pelvis may develop concomitant with the scoliosis and become so prominent that one lower extremity will appear shorter than the other when the patient lies flat on his back. Such a scoliosis can be made more obvious by having the patient bend forward. He will deviate toward the concave side.

3. Spasm of the erector spinae muscles. The patient is requested to stand in his normal posture, with heels together. The examiner palpates the erector spinae muscles on either side of the lumbar portion of the spine. One can soon learn to differentiate a normal from a spastic muscle. A normal muscle can be easily indented with the tips of the fingers and has the same consistency on both sides. These muscles may become so spastic as to feel boardlike and may stand out like whipcords to inspection. There is often an unequal spasticity on the two sides. If one has the patient extend his back a little the spasticity will not be entirely relieved.

4. Bending of the back is limited and painful. The patient is asked to bend forward, backward and to each side as far as he can or until he experiences pain. Forward bending is more consistently painful, the pain being referred to the region of the lumbosacral joint and often down some portion of the sciatic distribution.

Tests Made with Patient Lying Down:

5. Patrick's test and straight leg raising test. Patrick's test is performed by the placing of the ankle of one lower extremity on the leg of the other, just below the knee. Some pressure is then made downward on the bended knee. In the case of disease of the hip joint this maneuver is usually painful, but it is almost always painless in uncomplicated herniating intervertebrbal disk.

The straight leg raising test is performed by an attempt to raise the straightened lower extremity to as far as 90 degrees to the body. This

test is almost always productive of pain in the back, hip or sciatic nerve and especially in the latter on the painful side. The pain is due to stretch of a hypersensitive sciatic nerve. While the test almost always gives positive results on the side of the sciatic pain, the results are just as consistently negative on the normal side.

Kernig's test is an equivalent test and is performed by first flexing the thigh on the hip to 90 degrees and then extending the leg on the thigh.

6. Circumferential measurement of the leg at the greatest bulk of the calf muscle. Particularly in long-standing herniating disks, atrophy of 1 to 2 cm. can be demonstrated on the side of the sciatic pain. The finding is consistent enough to represent a true atrophy that results from long-standing compression of the motor component of a nerve root.

7. Demonstration of hypalgesia and diminished tickle on the sole. When one becomes experienced in performing the test for hypalgesia and diminished tickle on the sole, one can practically always demonstrate a diminished sensibility to pinprick in cases of herniating disk below the fourth or fifth lumbar vertebra. An ordinary straight pin is probably the best instrument. A needle is too sharp. The skin should be pricked just hard enough so that in normal zones the element of pain is minimal. The examiner should explain to the patient that he intends to prick the skin lightly on corresponding places on the lower extremities; that he will stick just as hard on one side as on the other and that the patient is to note whether the prick is more lively on one side or whether there is no difference. It is well to start high on the thighs to accustom the patient to the object of the test. Usually his response is that there is no difference on the thighs. Then the common sites of hypalgesia are tested. The zone where hypalgesia is most consistent is the lateral aspect of the leg, about midway between the knee and ankle. The spot that best represents the distribution of the fifth lumbar root (in the case of herniated disk below the fourth lumbar vertebra; the disk at the fourth lumbar space) is the medial aspect of the base of the large toe. At times it seems to be represented at the center of the ball of the foot and that region on the dorsum at the base of the second and third toes. Sometimes this central region of the foot appears to be more hypalgesic than the mesial aspect of the base of the large toe when the fifth lumbar root is involved. At other times, the reverse is true.

The locus that best represents the distribution of the first sacral root (in cases of herniating disk below the fifth lumbar vertebra, the disk at the fifth lumbar space) is the lateral aspect of the foot at the base of the small toe.

I feel that the important issue consists in clearly establishing hypalgesia in one or more of these significant loci on the foot and thus confirming the possibility of herniation at the fourth or fifth lumbar disks or both.

I have not yet convinced myself that one can differentiate between the fourth and fifth lumbar disks by the sensory test or by the status of the ankle jerk sufficiently to guide the surgeon in his exploration of one to the exclusion of the other.

I have observed that the sensation of tickle when the sole is lightly stroked is about as consistently diminished as sensibility to pinprick on the side of the pathologic changes.

8. Tenderness of the spine and loins. The patient is asked to turn on his side. Firm pressure on the fourth or fifth lumbar spines is often painful. Just as often, pressure in the loin lateral to the lumbar portion of the spine is painful on the side of the sciatic radiation and is not painful on the normal side.

9. Tenderness of the sciatic nerve and calf muscle. The patient is asked to lie on his stomach. With pressure along the course of the sciatic nerve with the finger tips, tenderness or soreness of the nerve on the painful side will be noted by the patient. Likewise, the calf muscle will be tender on squeezing on the painful side when compared with that on the normal side.

10. Patellar and achilles reflexes, or knee and ankle jerks: While the patient is lying on his stomach, he should adjust himself so that his feet extend beyond the end of the examining table. It is well to put slight pressure on the ball of the foot while the achilles tendon is briskly tapped. If there is any doubt about the equality of the reflexes on the two sides or if they are both absent, the patient should be placed in the optimum position for testing the ankle jerk. He should kneel in a chair and face the back of the chair. The ankles only should clear the chair and should be relaxed. If both ankle jerks are absent, reenforcement should be tried by the patient's clasping his hands and pulling while the test is being made. Sometimes one can bring out a diminished ankle jerk on one side by repeatedly tapping the tendon in moderately quick succession. On the side of the pathologic changes the reflex will "wear out" after three or four taps, while it persists indefinitely on the normal side. It is also helpful to try the minimal force of the reflex hammer that will cause a reflex response. Small differences in the response on the two sides can be effectively demonstrated in this way. That is, the minimal tap which causes a response on the normal side may fail to evoke a response on the affected side. Tendon reflexes are so consistently equal on the two sides in a normal subject that any definitely proved diminution on one side, however small, is significant.

I have only rarely encountered a patient who presented a diminished knee jerk that was due to chronic intraspinal herniation at the fourth or fifth lumbar disks. Such a finding should certainly cause one to consider the possibility of a caudal tumor, a herniating disk at a higher lumbar seg-

ment or some other lesion. However, I have operated on 2 patients who presented definitely diminished knee jerks and absence of ankle jerks on the painful side. The sciatic pain in both patients was severe, of sudden onset, unrelenting and of only two to three months' duration to the time of operation. Both patients also complained of numbness and hypalgesia to pinprick as high as the second lumbar distribution on the painful side. Both presented extrusion of sequestrated nuclear material through erosions in the annulus at the fifth lumbar disk, and there was no herniation or other lesion at a higher level. The knee jerks became equal some weeks following operation. This teaches only that an acute severe compression of a nerve root may cause a depression of the deep reflex at a higher level as well as hypalgesia at a higher level.

I have encountered 2 patients who presented diminished knee jerks due to herniation of the fourth lumbar disk into an intervertebral canal, with consequent compression of the fourth lumbar root (see extended exploration for herniation in an intervertebral canal).

About 50 per cent of the patients with herniating disks at the fourth or fifth lumbar vertebrae will present diminished or absence of ankle jerks on one side. I have encountered a few patients who presented an absence of ankle jerk on the side opposite to the sciatic pain. I have recently operated on a patient whose ankle jerks were equal a few days before operation. At the first examination, five months before, when sciatic pain had first appeared and was severe, the right ankle jerk could not be elicited. There was a pronounced herniation at the fifth lumbar disk on the right. Hence, if an ankle jerk is not diminished at the time the patient is examined, it does not necessarily follow that this was so at the time when sciatic pain was acute.

These detailed remarks concerning the ankle jerks have been made purposely because an ankle jerk is an important sign. Misinterpretation can easily be made by persons who have not particularly trained themselves in the obtaining of reflexes. In cases of unilateral, chronic or recurring pain in the sciatic distribution and in patients who present some of the symptoms and signs as described, a diminished ankle jerk makes the diagnosis of herniating disk mandatory until otherwise proved. The finding is, of course, not necessary for the diagnosis.

One should always include in the examination at least the tests for the abdominal, cremasteric and plantar reflexes and for genital and perianal sensibility. Abnormal responses may give a clue to other and rarer types of pathologic changes.

V. RARER SYMPTOMS AND RARER CASES OF HERNIATING INTERVERTEBRAL DISK

1. *Pain in the Back of the Neck Due to Herniating Lumbar Disk.*—I have seen 6 patients who complained of pain in the back of the neck, in

addition to other symptoms. This caused some confusion at first, but the symptom disappeared with the others after operation. It is undoubtedly due to spastic erector spinae muscles, the effect of the spasticity reaching as high as the back of the neck. Some of these patients complained of headache, which disappeared along with the other symptoms after operation. Stiffness and pain in the muscles of the back of the neck could logically have provoked a generalized headache.

2. *Acute Rupture of a Part of the Nucleus Pulposus Without Antecedent Pain Low in the Back or Other Symptoms.*—There have been 8 cases of rupture of part of the nucleus pulposus without antecedent symptoms in my practice. The duration of the symptoms has been two weeks to one year until the diagnosis was made. Either the patient was confined to bed from the sudden onset of sciatic pain, or else the latter maintained its intensity until the sequestrated nucleus pulposus was removed. The pain was excruciating, and the straight leg raising test gave definitely positive results. In most of the patients the entire lower extremity seemed painful. That is, the patient did not refer the pain as strictly to the course of the distribution of the sciatic nerve as does the usual patient with herniating disk. In cases of more insidious development the sciatic pain is more delineated. Also, in acute cases, the whole lower extremity is likely to be hypalgesic. This is not out of keeping with altered sensibilities when the onset of pain is sudden and excruciating. The following are illustrative cases.

CASE 1.—H. D., a youth aged 17 years, was admitted to St. Joseph's Hospital, Denver, on June 27, 1945. He experienced sudden sciatic pain rediating to and involving the calf muscle on the left side only. The incident occurred one year before, when he lifted a heavy object and the pain persisted. He denied the presence of pain low in the back either before or after the onset of sciatic pain. There were the usual symptoms and signs of herniating disk. At operation, a pronounced herniation was disclosed on the left side of the fifth lumbar disk. It displaced the first sacral root and severely compressed it against the ligamentum flavum. When the root was dissected and reflected mesially, the disk capsule ruptured spontaneously and a sequestrated portion of the nucleus extruded itself. It came from a well formed pocket, and I estimated that only about one third of the nucleus had sequestrated. The rest of the disk was firm and of normal integrity. Relief was immediate and recovery uneventful.

CASE 2.—W. M., a white woman aged 24 years, was admitted to St. Joseph's Hospital on July 12, 1945. She had experienced the sudden onset of pain which radiated typically in sciatic distribution from a point midway between the lumbosacral junction and the great trochanter of the femur[12] down to and involving the heel and instep of the right foot. The incident occurred while she was skiing six months before. She denied pain in the left lower extremity and denied pain low in the back either before or after the onset of sciatic pain. She presented the usual symptoms and signs of herniating disk. At operation,

12. This is such a common locus for the pain of herniating disk that for the sake of brevity I have designated it as "point A."

a completely sequestrated and pocketed rupture was disclosed on the right side of the fifth lumbar disk. I estimated that one third to one half of the nucleus had sequestrated and that the rest of the disk was of normal integrity. Only the fifth lumbar disk was explored.[13] Recovery was uneventful, and she was discharged, completely free of pain.

CASE 3.—V. G., a white woman aged 33 years, was admitted to St. Joseph's Hospital on June 26, 1944. While moving a rock about three months before, she "wrenched" her back. She denied pain low in the back previous to this incident. The lower part of the back continued to ache, and three weeks before hospitalization she felt sudden pain, which radiated typically in sciatic distribution to and involving the right ankle. She denied pain in the left lower extremity. She presented the usual symptoms and signs of herniating disk excepting the fact that the achilles reflexes were equal. At operation, a pocketed and completely sequestrated portion of the nucleus was found on the right side of the fifth lumbar disk. I estimated that about one fourth to one third of the nucleus had sequestrated and the rest of the disk was of normal integrity. She made an uneventful recovery and was discharged free of pain. It is of interest that she experienced the sciatic pain while her husband was convalescing from an operation for herniating disk.

It is interesting to note that the first 2 patients were relatively young. It has been my observation that in the more youthful patients the complaint of pain low in the back, if any, accompanying sciatica is less prominent than that in older patients. This raises the conjecture that partial sequestrations may tend to progress to completion more rapidly than complete degeneration of the entire disk.

The nature of the pathologic change and its development, especially in such young patients, when contemplated in all its aspects, favors the contention that the disintegration and sequestrations are on a developmental basis. It is true that these patients dated the acute onset of sciatica to a strain of the back, but a study of the pathologic changes makes it obvious, I feel, that the strain was only an incidental and a precipitating factor; that is, the strain was associated with sufficient stress to disrupt a preexisting weak and degenerating disk.

I have recently examined a boy 9 years of age who experienced the sudden onset of typical sciatic pain on one side, which confined him to bed, and who presented all the symptoms and signs of herniating disk. He denied pain low in the back and could not recall ever having sprained his back. He has not yet come to operation.

3. *Absence of Achilles Reflex on the Side Opposite That of Sciatic Pain.*—The combination of the absence of the Achilles reflex on the side opposite that of the sciatic pain has already been mentioned. There have been 4 cases in my experience, and, as might be suspected, the disk was herniated clear across the spinal canal, so that the nerve roots on each

13. In a case of this kind, in which there is sudden onset of sciatic pain uncomplicated by long-standing pain low in the back and sufficient pathologic change found to explain the syndrome, I feel that one can reasonably forego exploration of the fourth lumbar disk.

side were compressed. Though the phenomenon seems strange, the only explanation is that the sensory component of the nerve root on one side bore the brunt of compression while the motor component sustained it on the other side.

4. *Large Ruptured Disk with Complete Caudal Lesion.*—There have been only 3 cases in my experience. The findings were those typical of complete caudal lesion at the fifth lumbar disk, anesthesia in the distribution of the first sacral roots down, absence of achilles reflexes and paralysis of the rectal and vesical sphincters. All patients made slow recoveries after operation.

5. *Symptoms of Herniating Disk Referred to Phantom Extremity.*—A man of 60 had an amputation high in a thigh thirty years ago because of a crushing injury to the leg. The stump was good, and though he sensed the presence of the phantom leg he never experienced pain. Six months ago pain low in the back and typical sciatic radiation to the phantom foot began to develop. The stump was not locally tender, but flexion on the hip aggravated the sciatic radiation. Though the patient has not yet come to operation, I am convinced that he has a herniating disk on the side of the amputation.

6. *Pain in Only the Foot and Leg.*—There have been 2 patients who complained of pain only in the ball and instep of the foot and pain in the lateral aspect of the leg on one side. They described the pain as beginning in the foot and going up the leg. The foot was tender and sensitive, so that stepping on it or putting it into a shoe was painful. They had been from place to place, acquiring different types of shoes and getting repeated roentgenograms of the foot, the latter being always normal. The fact that they never complained of pain low in the back or pain above the knee made the correct diagnosis obscure and unsuspected. When they described, located and traced the course of the pain, however, the distribution of the single root was betrayed. This together with paresthesia, hypalgesia in root distribution and diminished ankle jerk established a diagnosis. Persistent pain in a foot and perhaps leg, especially when unilateral and when no other cause can be found, should arouse the suspicion of a herniating disk.

7. *Pain in the Rectum.*—I have seen a few patients who complained of pain in the rectum and pain on defecation at times. No local cause for the pain could be found. The complaint was in addition to those related to a herniating disk, and it disappeared after operation. I have suspected that it might be due to spasm of the levator ani muscles and other muscles of the pelvic floor, being on the same pathophysiologic basis as spasm of the muscles about the lumbosacral and sacropelvic regions.

8. *Signs Contaminated by Lesions of the Upper Motor Neuron.*—There have been 2 cases with lesions of the upper motor neuron in my

practice. In 1 there was a Babinski sign on the side of the herniation of the disk due to an old injury of the spinal cord. The herniating disk was at the fourth lumbar space. In the other case there was a Babinski sign and a hyperactive knee jerk and ankle jerk on the side of the sciatic pain. The hyperreflexia was due to an old injury to the brain. In such cases the diagnosis of herniating disk at the fourth or fifth lumbar space is more difficult. However, the description of typical sciatic pain and the demonstration of hypalgesia in the fifth lumbar or first sacral distribution is strong evidence for herniating disk. One should not let the disturbing signs of the upper motor neuron eliminate the diagnosis, providing there is clear evidence for the existence and cause of the independent lesion. The cause of the signs of the upper motor neuron must, of course, be established also. In the 2 cases in my experience they were due to old injuries.

VI. THE ROENTGENOGRAM

Unfortunately, there is little in the ordinary roentgenogram of the lumbosacral portion of the spine that would substantially warrant the diagnosis of herniating disk. Narrowing or collapse of a disk arouses interest. I am not yet convinced concerning its reliability as a pathognomonic sign. I have operated on several patients who presented complete collapse of disks in the roentgenograms. One was in the cervical region, between the sixth and seventh cervical disks, and no herniating disk was found. In 1 case, that of a woman (O. H.) 48 years of age, the patient complained of pain low in the back which had been a severe handicap to her for twenty-eight years. She had experienced radiating pain to the calf muscles on both sides and sensations of numbness in both legs. The roentgenogram showed an almost complete absence of the intervertebral disk at the fourth lumbar space (see figure 2). At exploration, no rupture of the disk was found. A bulging annulus was present, which narrowed the spinal canal. When the annulus was incised no nucleus pulposus could be found. The vertebrae were closely opposed but not fused. Compression of the roots could be attributed to the bulging annulus and to the narrowing of the intervertebral canals. In such cases, the nerve roots might properly be widely decompressed and the bulging annulus excised, as was done in this patient. The result was good, with pronounced alleviation of the long-standing symptoms. I cannot explain the loss of disk substance, but it was not herniated into the spinal canal.[14] I feel that this represents a congenital anomaly and that the nucleus failed to develop embryologically. It is hardly conceivable that the nucleus could have been "absorbed." If this were possible, then more such exam-

14. See discussion on "extended exploration for herniation in an intervertebral canal" under section on "operation." Information concerning herniation and rupture of the intervertebral disk anteriorly is as yet meager.

ples should certainly have been encountered among the large number of degenerating and herniating disks that have been explored.

There has been only one exception to the rule of normal roentgenograms. In herniations that have been present for many years a posterior lipping of the vertebrae may occur, that is, a sizable cone of bone develops around the base of the protruding disk. This was demonstrated in the roentgenogram in 2 patients, 1 of whom had symptoms for twenty years. After examining many roentgenograms, I have been unable to find any other incontrovertible clue to the diagnosis. Physiologic scoliosis and

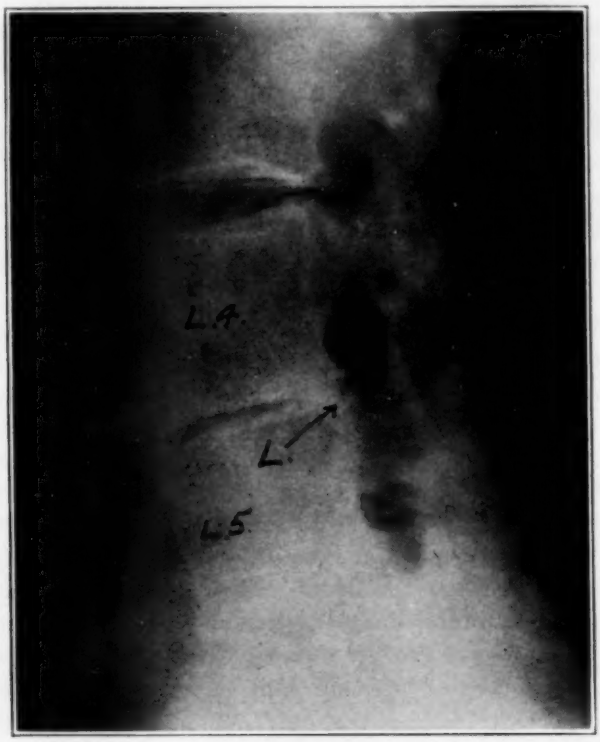

Fig. 2.—Roentgenogram of the lumbar portion of the spine in the case of O. H. Note the close approximation of the fourth and fifth lumbar vertebrae. The bony lipping at *L* together with a bulging annulus narrowed the spinal canal and crowded the fifth lumbar roots. The vertebrae were not fused, but tissue resembling nucleus pulposus could not be found. This is probably a developmental anomaly and not due to absorption of a nucleus pulposus.

diminished or absence of lordosis are commonly associated with herniating disks but are only contributory in value.

However, the anteroposterior and lateral views of the lumbosacral portion of the spine should always be taken before operation is resorted to, if only to rule out skeletal pathologic changes. This precaution has saved me the embarrassment of exploring several metastatic neoplasms.

Spondylolisthesis may be responsible for a syndrome that simulates herniating disk, but the surgical indications are different from those related to herniating disk.

In 1941 I attempted to find some roentgenologic means whereby one might establish the presence of a soft, degenerating disk. With the idea that an abnormally soft disk might be more compressible than the normal, controlled roentgenologic studies were made as follows: Lateral exposures of the lumbosacral portion of the spine were taken, the exposure being centered through the fifth lumbar disk. Exposures were made with the patient in the erect posture and when hyperextended and when hyperflexed. Normal subjects and patients with disks which were later proved to be degenerating and herniating were studied. Careful measurements of the changes in the width of the disks with the extremes of posture were made. The most pronounced change in the shape of the intervertebral disks was associated with the flexed posture. When the patients changed from erect posture to extreme flexion, the distances between the anterior lips and the posterior lips of adjacent vertebrae changed sufficiently to provide substantial measurable differences. However, I was unable to establish an index of change that had sufficient value in differentiating the normal from the abnormal. The normal findings in no way discredit the concept of the soft disk and the unstable joint. The joint may be considerably weakened without providing gross dependable changes in measurements of disks in this experiment.

In earlier days, when an understanding of the syndrome of herniating disk was in a nebulous state, congenital malformations of the lumbosacral part of the skeleton gave much concern. Such were sacralization of the fifth lumbar vertebra, elongation of the transverse process of the fifth lumbar vertebra, variation of the articular facets and defects of the neural arches. Experience has led to the conclusion that given a syndrome of herniating disk these skeletal malformations may ordinarily be disregarded. Furthermore, the incidence of such malformations in painless backs is high.

A patient with a syndrome of degenerating or herniating disks may reveal a mild or moderate degree of lipping, especially of the lumbar vertebrae. One should not be too hasty in attributing the symptom complex to arthritis and in relegating the patient to the limbo of the lost. Arthritis has tended to become a diagnostic panacea when other causal factors for symptoms are not understood. The "x-ray arthritis" is likely to be only incidental, especially when a patient has no pain or symptoms above the lower part of the back. In any case, a patient deserves thorough investigation before being labeled "arthritic."

In follow-up roentgenograms about three to four months after thorough curettement of a disk, I have found that the disk space will commonly but not always become narrower by about one third of the

space shown preoperatively. In 1 patient it decreased by one half. I have not found one to collapse completely. Up to one year after operation I have yet seen no evidence of ossification of the disk. Keyes and Compere [8] reported a case of ossification of the nucleus pulposus, but it must be rare. They pointed out that only the epiphysial ring (the rim around the vertebral body that is adjacent to a disk) has bone-forming properties. This may explain the uncommon ossification of the disk and the relatively common lipping or spur formation. Indeed, the new bone may be a traction spur, which indicates an excessive strain at the junction of the vertebral rim and the annulus. This may possibly indicate a weakness and an inefficiency of the intervertebral disk (see case of A. H., under extended exploration for herniation in an intervertebral canal in the section on operation).

Recapitulation.—The thesis presented in this paper involves only going back a step and recognizing that the intervertebral disk must undergo degeneration before it herniates and ruptures. When it is undergoing the process of degeneration, it serves as an inadequate and inefficient joint. As a result of this, undue stresses and strains are placed on the perispinal and lumbosacral ligaments and muscles. This, in turn, is the cause of pain low in the back. It is more likely that strain of the short ligaments is the cause of the acute pain, while muscle spasm is secondary. The mechanism of the acute pain or "catch," which is so commonly parasacral, is not unlike that of a sprained ankle. In time, the annulus fibrosus, or the tough capsule which encases the nucleus pulposus, becomes so thin and inadequate that it can no longer retain the nucleus pulposus under strain and consequently herniates and finally ruptures, extruding the sequestrated nucleus into the spinal canal. Concomitant with this the nerve root adjacent to the disk is compressed and the symptoms and signs of compression of the nerve root supervene—to wit, radiating pain in the sciatic distribution, pain on coughing and sneezing and paresthesias.

The statement that "in time the annulus gives way to herniation" may be modified in the light of this observation: The incidence of the "weak lower part of the back" is high, and the severity of pathologic changes and symptoms varies considerably from a mild degree to one which is a serious handicap, because of both chronic pain and a physical incapacity for labor and for making a livelihood. However, many of the afflicted persons never progress to the stage of severity that would reasonably demand operation. The process of degeneration may be slow or may possibly even become quiescent. The nature of the patient's activity may be such that he makes no great demands on his back and he adjusts his life and activity so that in spite of the defect he can live his normal life in relative comfort. In some instances the degeneration progresses to complete dissolution of the disk, and this may obtain

spontaneously without postulation of the factor of trauma or strain. But, obviously, many patients never progress to this stage and never require surgical intervention. In cases of moderate severity, the patient may be relieved temporarily or permanently by the aid of some partially stabilizing appliance such as a suitable corset or brace. In any case, I feel that this chronic deficiency low in the back is in the majority of cases due to pathologic changes in the intervertebral disks, which are probably of a developmental origin. Given such a defect, they may or may not progress to a stage of severity that warrants surgical intervention. This is determined by symptoms and by the attitude and election of the patient. When one is formulating the diagnosis, prognosis and advice to the individual patient, I think that it is helpful to have this concept in mind.

To summarize, the distinction must be made between a degenerating disk and a herniating disk. The symptoms and signs of the former are those related to an inadequate syndesmotic joint, which renders an instability of the lumbosacral portion of the spine. Strain on the periarticular structures is the cause of the symptoms. When the nucleus pulposus herniates, the symptoms and signs of compression of the nerve root are superimposed.

VII. PATHOLOGY

In order to understand and recognize the characteristics of the degenerating or pathologic intervertebral disks, one should be well acquainted with normal disks. Studies of normal and pathologic disks are being made in collaboration with Dr. Charles B. Kingry, acting pathologist for St. Joseph's Hospital. The objectives are, first, to study the gross and microscopic characteristics of normal intervertebral disks in each decade of life and, second, to attempt to establish some criteria by which the degenerating disks can be not only differentiated microscopically from normal disks at any given decade but graded in respect to early, moderate and advanced degeneration. We feel that it is more appropriate to report the results of these studies in a separate communication. However, for the purpose of this report a brief discussion of the essentials is as follows: The normal intervertebral disk is white. It is classed as a symphysis type of amphiarthrotic joint. It is composed of three essential elements: (1) the nucleus pulposus, (2) the annulus fibrosus and (3) an upper and lower hyaline cartilage plate.

The nucleus pulposus is a centrally placed amorphous mass of tissue which has a pearly translucency (see figure 3). In the fresh state it appears wet and jelly-like, and yet one is surprised to find its degree of toughness if an attempt is made to cut or curet it away. Fluid does not seep from the cut surface. It appears to be lobulated, so that it reminds one of boiled tapioca. It is easily compressible, like fine-meshed sponge rubber, and is resilient, so that it resumes its former shape. It

is difficult to compare it with any other known structure; the nearest comparison I can make is to partially hydrated gelatin. The nucleus pulposus is evidently under great tension in youth and middle age. Figure 3 is a photograph of one half of a section of spine cut through the sagittal plane. When the specimen was cut, the nucleus bulged about ¼ inch (0.6 cm.) from the cut surface in each half. It is this resilient fluid structure that makes possible the mobility of the spine and provides the cushioning effect necessary to the lengthening and shortening of the spine. In a newborn infant the nucleus is soft and mushy and well delimited from the annulus fibrosus and does not appear to be under great tension. In old age it loses its compressibility and resiliency and becomes less differentiated from the annulus. In youth and middle age it appears as that shown in figure 3. It is important

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EXPLANATION OF FIGURES 3, 6 AND 7

Fig. 3.—Photograph of vertebral column cut through the midsagittal plane, showing the third, fourth and fifth lumbar and first sacral vertebrae with intervertebral disks. The specimen was taken at autopsy from a man 35 years of age, who died of peritonitis. There was no history of pain low in the back, and the spine is considered to be normal. The specimen was photographed in the fresh state.

L. 4 indicates the fourth lumbar vertebra; *A. L. L.*, the anterior longitudinal ligament (firmly attached to disk and vertebra); *A. F.*, the annulus fibrosus; *N. P.*, the nucleus pulposus; *C. P.*, the cartilage plate, and *P. L. L.*, the posterior longitudinal ligament (attached to the disk but unattached to vertebral body; it adds relatively little strength to the annulus fibrosus).

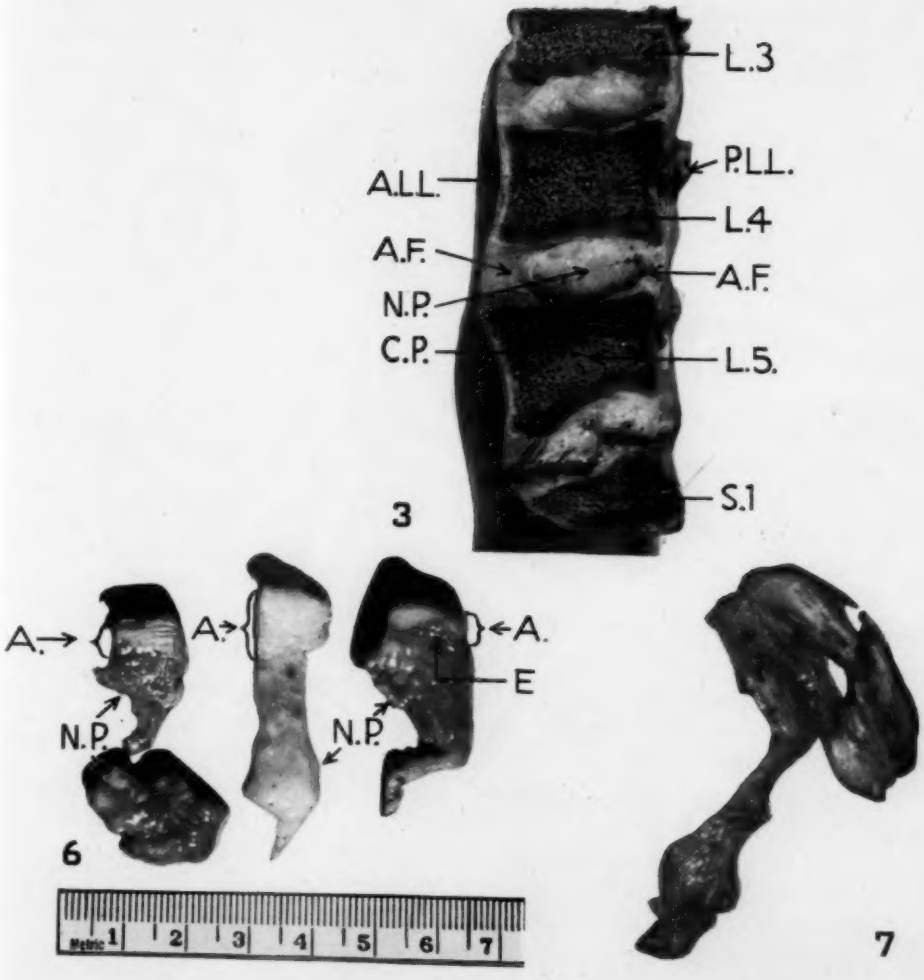
Note the bilobed character of the nucleus pulposus between *L. 5* and *S. 1*—a developmental defect.

Fig. 6.—Photographs of specimens from intervertebral disks (photographed in the fresh state). The specimens were cut from the disks posteriorly with a sharp-pointed blade. The central specimen is from a normal disk (taken from the fourth lumbar disk in the specimen shown in figure 3) Note the normal thickness and laminated structure of the annulus (*A.*) and the translucent homogeneous character of the nucleus pulposus (*N. P.*).

The two end specimens were taken from a white woman 28 years of age. She complained of severe chronic pain low in the back without sciatic radiation. Both the fourth and the fifth lumbar disks were degenerating, and after thorough curettement a good result was obtained. The specimen on the left was taken from the fourth lumbar and the one on the right from the fifth lumbar disks. Note the beefy red color of the tissue. The annulus (*A*) has been greatly thinned and has lost its laminated structure. Note the complete erosion at *E*. Herniation and rupture of the nucleus would undoubedly have occurred at this locus in a relatively short time.

This is probably an example of a rapid degenerative process. In time this nucleus would become drier and more fibrous and would sequestrate. Not all degenerating disks are red. This appears to characterize some of the earlier and more acute degenerations.

Fig. 7.—Photograph of a block from a degenerating disk at the fourth lumbar space in a patient who complained of severe chronic pain low in the back with reflex sciatic pain. By reflection of the dura first from one side and then the other, a block of tissue was removed, which represented the entire width of the disk. The nucleus and most of the degenerating annulus were beefy red in appearance. Note the complete erosion in the central region of the annulus. The overlying annulus at this location had the thinness of tissue paper, and mild herniation had already begun.



Legends for Figures 3, 6 and 7 on Opposite Page.

to note that the normal nucleus in youth and middle age is not friable, mushy, fibrous or stringy and does not come away in large pieces or fragments if one attempts to pull it with a tissue forceps or hemostat.

Keyes and Compere [8] pointed out that until birth the notochord serves as the chief source of the nucleus, but in a 4 year old child notochord cells are difficult to find, since they have undergone mucoid degeneration. The inner aspect of the annulus fibrosus contributes the fibrous tissue found in the nucleus and enlarges it. This process of maturation, by replacement of the gelatinous mucoid material with interspersed cells of fibrocartilage from the annulus, progresses continually throughout life until the senile intervertebral disk loses its gelatinous character and resiliency.

The annulus fibrosus is a laminated structure that encases the nucleus pulposus and has almost the toughness of leather. It is thin, superior and inferior to the nucleus, for the latter is well supported by the cartilage plates and vertebral bodies at these loci. The annulus is evident anteriorly and posteriorly where a strong capsule is necessary to retain the nucleus. It is about ¼ inch thick posteriorly and about ⅜ inch (1 cm.) thick anteriorly at the fourth and fifth lumbar segments.[15] The laminas of the annulus are of fibrocartilaginous structure and are so arranged that the fibers of adjacent laminas progress in opposite directions and crisscross or interlace each other. This arrangement provides the annulus with the unique property of being bendable, so that with change in posture of the spinal column it may bulge and retract like the bellows of an accordion and yet maintain adequate toughness and strength to retain the nucleus pulposus.

The Degenerating Disk.—The degenerating intervertebral disk is evident to macroscopic observation. The nucleus pulposus loses its translucency and evidently most of its water content. It undergoes a process of sequestration so that ultimately it becomes completely segregated from its confining structures and can be easily lifted in toto from its bed with tissue forceps. For convenience, I have referred to this as a "ripe" disk, because of the similarity to a "ripe" cataract. In the process of sequestration the nucleus becomes fragmented and stringy, so that large pieces may be pulled away with forceps. The fragments appear dry when compared with the glistening opalescent and wet appearance of the normal nucleus (see figures 4 and 10).[16]

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15. The annulus is thicker in front than behind in the cervical and lumbar regions, thus accounting for the lordotic curvature in these parts. It is of about equal thickness anteriorly and posteriorly in the thoracic part of the spine. The kyphotic curve of the latter is due to a difference in thickness of the vertebral bodies in the anterior-posterior direction.

16. Karl Neubeurger (University of Colorado School of Medicine) gave suggestions and aid in the preparation of the pathologic material for study.

Microscopic examination reveals that the mucoid structure of the nucleus is replaced by fibrocartilage to varying degrees. Instead of the nearly homogeneous matrix of the normal nucleus, one finds more distinct fibers. These fibers are the product of fibrocartilaginous cells and contain some collagen. They are exhibited better by the Van Giesen stain than by the usual hematoxylin-eosin stain, and I feel that the former is of greater value in studying and grading degeneration of disks. In one specimen the fibrocartilaginous tissue progressed to actual carti-

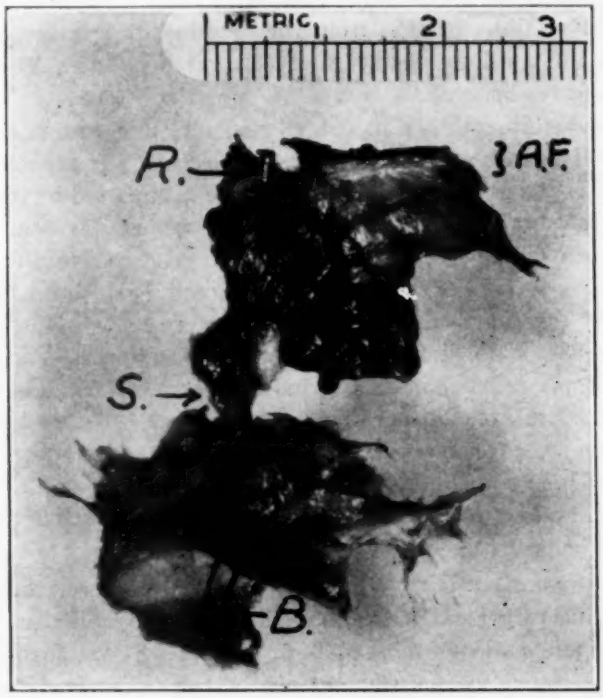

Fig. 4.—Photograph of unfixed specimen taken at operation from the fourth lumbar intervertebral disk in a man 27 years of age. The upper half of the specimen was cut "in block" from the disk and lifted out. The lower half of the specimen was a completely sequestrated portion of the nucleus pulposus, attached to the upper half by only a strand of tissue (*S*). *A. F.* indicates the degenerating annulus fibrosus (the intraspinal aspect) and *R.* the rupture through the annulus where nuclear material was extruding and compressing the adjacent fifth lumbar nerve root.

Note the dry appearance of the sequestrated nucleus and the frayed stringy margins. The degenerating nucleus was beefy red in color except for a few streaks of white tissue running through it. A block was taken through one of these white streaks at *B* for microscopic study. The white tissue proved to be cartilage metaplasia, while the red tissue proved to be dense fibrocartilage. A photomicrograph from this block is shown in figure 5.

laginous change in places (see figure 5). I have observed this in only one instance. I have never seen microscopic evidence of inflammation or necrosis in a degenerating disk.

The annulus also degenerates, losing its laminated appearance and structure (see figures 4, 6 and 7). It ultimately becomes so thin and inadequate that it can no longer retain the sequestrating nucleus, and the latter is extruded into the spinal canal. The significant fact is that the process of degeneration involves and extends into the annulus and destroys its normal structure. Complete erosion usually occurs first in a limited and small area, and it is at this locus that herniation, rupture and extrusion of the nucleus take place (see figures 4 and 7). When dissolution of the annulus occurs, the syndesmotic joint between the

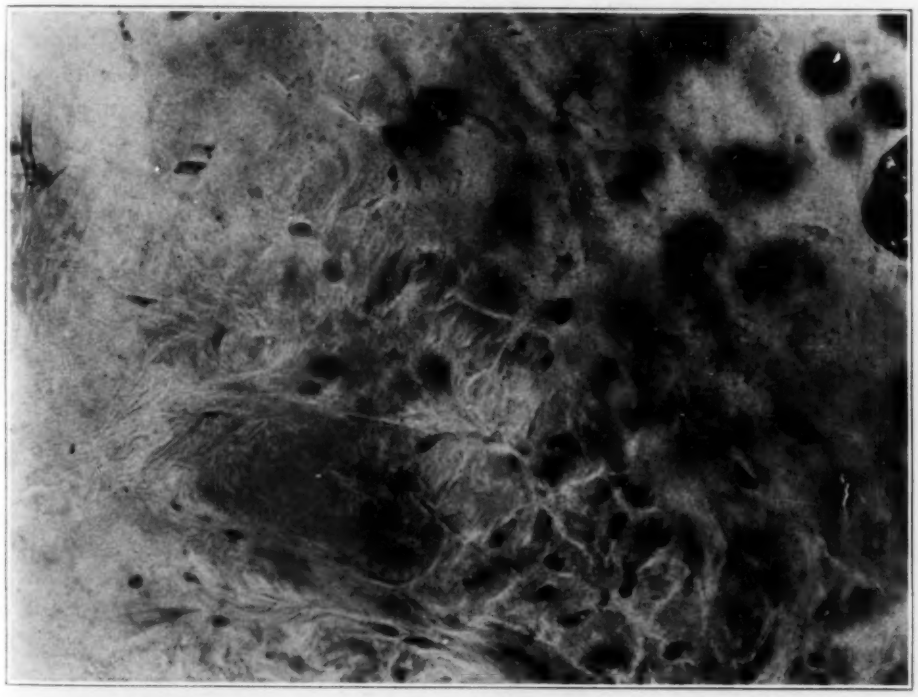

Fig. 5.—Photomicrograph of a section taken from the block (*B*) in figure 4. Hematoxylin-eosin stain was used. The section shows dense fibrocartilage which has undergone cartilage metaplasia on the right. This is the only instance of dense cartilage metaplasia which I have encountered in a degenerating disk.

two adjacent vertebrae is weakened and can no longer maintain the essential axial strength and stability of the spine at that joint. Other structures in and about the spine must then support its integrity with every change in posture. One might say that the fulcrum of the levering forces is proportionately transferred to the articulating joints and perispinal ligaments and, remotely to the perispinal muscles. The process of degeneration is undoubtedly a slow one, measured probably in terms of years. If the annulus maintained its normal structure and the nucleus alone degenerated, I doubt that the latter could ever herniate and I doubt

that the patient would experience the symptoms of the weak lower part of the back.

It is because of these observations and because of the probability that the degenerative process may likely progress to involve the entire disk that I have felt it advisable (in most cases)[17] to remove as much of the nucleus as possible and to remove all the annulus posteriorly, approaching it from both sides of the spinal canal. This thorough removal of the pathologic portions of the disk prepares the way for the development of a firm fibrocartilaginous scar in the cavity that is left, thus establishing a fusion at the place where it should be made. That such a scar does develop has been proved by direct observation in the following case:

L. I., a white woman aged 29 years, was admitted to the University Hospitals, Iowa City, in January 1943. She complained of severe chronic pain low in the back, with exacerbations off and on for four years. She referred the pain to the region of the lumbosacral joint and denied sciatic radiation. Examination indicated a stiff, painful lower part of the back, with spasticity of the erector spinae muscles. The thighs were somewhat tender on squeezing, but there were no signs of compression of the nerve roots. Roentgenograms of the lumbosacral portion of the spine were normal. An impression given by the Department of Orthopedics, State University of Iowa College of Medicine, was chronic lumbosacral strain.

A laminectomy was done on Feb. 4, 1943, and the disks at both the fourth and fifth lumbar spaces were found to be degenerated. The annulus was thin and soft, and a tissue forceps could be plunged through it as easily as one can puncture a sheet of paper. There was no herniation or compression of the root by inspection. The annulus was cut away, and both disks were thoroughly curetted. The histologic examination was reported as showing degenerated and hyalinizing fibrocartilage. The patient made an uneventful recovery and in twenty-five days stated that she was free of pain. She was gratified with the result and "felt like she had been given a new back."

Three months later she returned to the hospital, complaining of the development of a relatively acute pain low in the back. She presented the symptoms and signs of what I should now recognize as being the result of a ligamentous strain, with its associated muscle spasm. Such an episode occasionally occurs even as long as two or three months after operation and is attributable to an (as yet) insufficiently stable lumbosacral portion of the spine. For this type of fibrocartilaginous fusion one should think of results in relation to the magnitude of the element of time in at least the same terms as one would for a tibial bone graft across the lumbosacral joint. This is especially true when the use of body casts is being avoided. The patient referred to here would now be treated conservatively to tide her over the acute episode. But at that time, not being informed on all the factors, I felt that it was advisable to reexplore the wound.

17. In cases in which a small portion of the disk has undergone complete sequestration (pocketed type) and the rest of the disk appears firm and of normal integrity, one is licensed to feel that the degeneration was only partial and localized and has progressed to completion. In this instance the remaining disk is not incised.

Reexploration.—The soft tissue scar was tough and firm. No dead or fluid spaces had persisted. A firm and tough fibrous scar had developed across the interlaminal spaces. The dura was somewhat adherent to the overlying scar but could be separated by a blunt instrument with relative ease. The dural sheaths of the nerve roots could be reflected likewise from the disks and vertebrae with ease. The intervertebral cavities which remained after curettement three months ago were now completely filled and replaced by pearly white fibrocartilaginous scar tissue. By inspection I did not feel that the intervertebral spaces had decreased to any appreciable extent in the direction of the spinal axis. It was relatively difficult to plunge a pointed stab blade into the new disk. The one at the fifth lumbar space appeared homogenous throughout, as firm in the center as on the spinal surface, and presented much the same quality and consistency

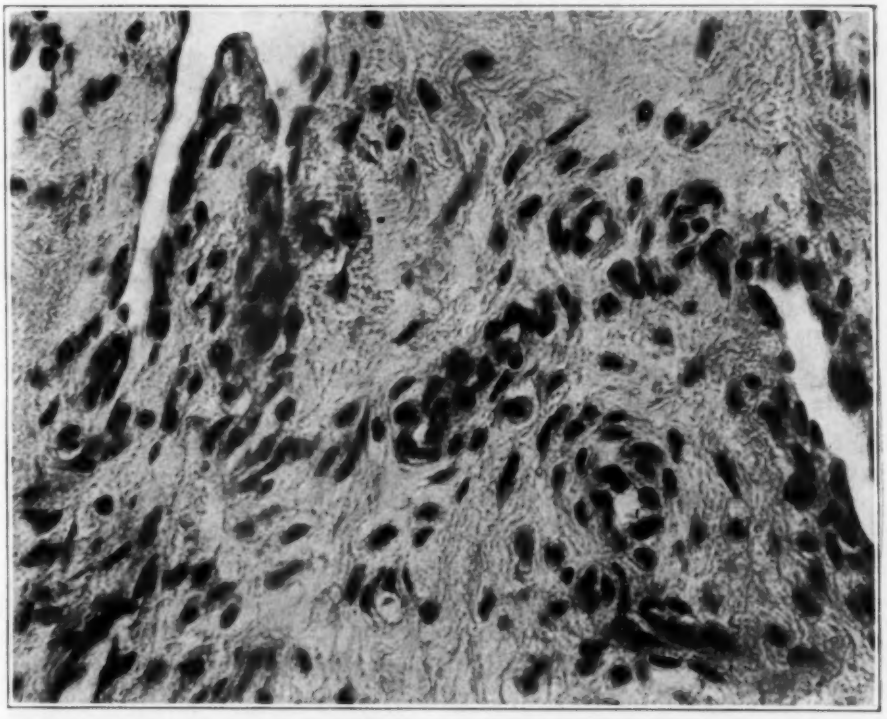

Fig. 8.—Photomicrograph of specimen of healed disk in the case of L. I. The block of new tissue was taken in the usual manner three months after thorough curettement had been done. The cavity was completely repaired with tough fibrocartilaginous scar tissue. Note the abundance of young fibrocartilage cells engaged in the process of repair.

as does cartilage. A block was removed for microscopic study. The latter showed the development of new fibrocartilaginous tissue, with invasion of many young cells (see figure 8).

The patient made an uneventful recovery from the operation and from the episode of acute pain low in the back. Follow-up letters were gratifying and, so far as I know, she has remained free of pain to the present time.

VIII. ETIOLOGY

The consensus at present is that trauma plays the important role as a causal factor of herniating intervertebral disk. This concept has even given rise to the term "fractured disk." I should like to present considerable evidence, however, that trauma or injury of the back probably is not the initial cause of the changes in the disks that ultimately lead to herniation but only aggravates, hastens or precipitates the symptoms of an already existing degenerating and inadequate disk.

1. As brought out in a previous report,[3] about one fourth of the patients presenting the syndrome of herniating disk cannot recall an injury to the back of any consequence. The signs and symptoms develop gradually and are not associated with trauma. It is true that three fourths of the patients do recall one or more incidents of injury to the back and to one of which they often date the onset of the symptoms. Some of these injuries are severe, such as falling several feet in a sitting position. Many of the so-called injuries are trivial in respect to traumatic force such as that which occurs when one lifts a suitcase or bucket of water. The incidence, however, is one of real injury to the back of the patient, because the "catch," or "snap," that he experiences in the lower part of the back or the hip, which may also be associated with sciatic radiation, is accompanied with severe and excruciating pain.

The great majority of patients who date their severe pain to a relatively recent injury will, if questioned, give the histories of previous pain low in the back, weak back, stiff back and episodes of pain low in the back that have often been experienced for many years. If the disk has undergone advanced degeneration and the annulus fibrosus has become so thin as to be an inadequate capsule, it is obvious that a crushing force or strain may provoke one of three occurrences. The soft disk, being an inadequate joint, may allow a too severe pull or sprain of the ligaments, muscles and tendons about the lumbosacral region. This is accompanied with a sudden sickening and aching pain comparable to that of a sprained ankle. A second possibility is bulging, or herniation, of the disk capsule into the spinal canal, with consequent compression of a corresponding nerve root and with its attending symptoms, the severity of which depends on the degree of herniation. Third, the capsule may rupture and varying amounts of a sequestrated nucleus pulposus be extruded. In such a case compression of the root is severe and unrelenting, and such patients are usually confined to bed until relieved by operation. Hence, it is perfectly reasonable to believe that trauma, mild or severe, may be only an aggravating factor to an existing pathologic condition.

2. When an injury to the back is severe enough to cause a break in continuity or dissolution of tissue, one sustains a subluxation or dislo-

cation of a joint or a fracture. So far as I can ascertain, a normal intervertebral disk is the last structure to suffer fracture or damage. It is the vertebral body that is fractured. I have never witnessed a fracture or rupture of a normal intervertebral disk due to the usual injury of the back. It would be most difficult to believe that the type of injury of the back under discussion could possibly cause a herniation or rupture or "fracture" of a normal intervertebral disk and, moreover, leave the bony spine intact. Saunders and Inman [18] gave a good account of the pathologic changes of the intervertebral disk. In respect to traumatic rupture, they made the following statements:

> Traumatic rupture of the cartilage plate occurs in conjunction with compression fracture of the vertebral body, but it has been remarked how often the disk escapes injury even in the most severe lesions. . . . An important variety of trauma to the cartilage plate is that associated with marginal fracture of the vertebral body. These chip fractures are commonly anterior in position and are in themselves insignificant but, from roentgen evidence, are followed by collapse and thinning of the disk. . . .
>
> We should like to emphasize that posterior herniations are in the great majority of instances evidence of general disk degeneration.

3. The changes which occur in a disk that has progressed to herniation are changes that develop slowly and undoubtedly require considerable time to reach the end stage. I have had experience with some patients in whom acute sciatica developed, the onset of which was one to two months previously and which was attributed to an injury of the back. There were no antecedent symptoms. At exploration, ruptured disks were found, the sequestrated portion of the nucleus having been suddenly extruded into the spinal canal and accounting for the sudden, severe and unrelenting sciatic pain. In such a case, one is certainly tempted to view the lesion as a "fractured" disk which was sustained at the time of injury. Grossly and microscopically, however, it is obvious that the changes leading to the final stage had probably been progressing for years. Not only does the nucleus pulposus undergo the changes described, but it is necessary for the annulus fibrosus to degenerate if posterior herniation is to occur. When viewed in cross section, the annulus, posteriorly, is a laminated structure about ¼ inch thick and having the toughness of leather. It is hardly reasonable to believe that nuclear material could be squeezed through such a structure unless the latter had in some place lost its integrity through degeneration. Studies of disks in various stages of degeneration reveal that the annulus does take part in the degeneration, loses its "onion peel" appearance and becomes so thin as to be incapable of retaining the nucleus even under normal stress. Such a process is obviously not a sudden one

18. Saunders, J. B. de C. M., and Inman, V. T.: Pathology of the Intervertebral Disk, Arch. Surg. **40**:389-416 (March) 1940.

and cannot be attributed to an incident of trauma to the back which dates the onset of the symptoms of herniating disk. If one subscribes to trauma as the cause, one can only propose that some previous injury set into progress the changes in the disk described; however, this particular injury would not necessarily date the onset of the syndrome of the herniating disk.

4. Eighty-seven to 98 per cent of the herniating disks occur below the fourth or fifth lumbar vertebrae. This is an outstanding observation and one which has not been satisfactorily explained. Since the consensus favors trauma as the etiologic factor in pathologic changes in disks, it is only consistent to propose that stress and strain are greater at the lower two lumbar segments. This seems to be stretching a point rather far when one recognizes how sharp is the demarcation between the lower two lumbar disks and all those above in respect to incidence of herniation. Furthermore, it is uncommon to sustain compression fractures of the fourth and fifth lumbar vertebrae. Fractures are usually of the first and second vertebrae or higher, an indication in itself that the greatest flexion compressive strain is not at the fourth and fifth lumbar segments.

5. Embryologically, the nucleus pulposus is derived from a "pinched off" remnant of the notochord, and in the growth and development of these structures many displacements and abnormalities occur, such, for example, as Schmorl's node and spondylolisthesis.[19] If a degenerating intervertebral disk has a congenital or developmental basis, it is not unreasonable to expect the greatest incidence to be at the caudal end of the notochord. Note the defect in the fifth lumbar disk in figure 3. It is such that the nucleus has been divided into two parts.

In many instances of herniating disk one will find only a pea-sized herniation laterally placed. One finds that only a small part of the nucleus pulposus has sequestrated and rests in a walled-off pocket. The remainder of the nucleus is apparently normal. Furthermore, others, as well as I, have encountered herniating disks in patients whose ages ranged from 17 to 22 years who had no history of significant trauma to the back.

6. Inflammation has been kept in mind as a possible etiologic factor, and the beefy red appearance of some degenerating disks strongly suggests an inflammatory change. However, I have never been able to demonstrate the elements of the inflammation microscopically.

Therefore, when the three major factors in respect to the causation of degenerating and herniating disk are considered, namely, trauma, inflammation and faulty development, the evidence certainly promotes

19. Ehrenhaft, J. L.: Development of the Vertebral Column as Related to Certain Congenital and Pathological Changes, Surg., Gynec. & Obst. **76**:282-292 (March) 1943.

a strong consideration that favors faulty development as the primary causal factor. If faulty development is an important factor, the nature of the pathologic changes still, nevertheless, remains unexplained. Deficient blood supply is a possibility that might at first seem to merit consideration, but Keyes and Compere [8] stated that the intervertebral disk contains neither blood vessels nor nerves and that its nutrition is supplied entirely by the lymph stream. These authors found congenital imperfections in the cartilage plates and gave evidence to show that splits and tears may be caused by trauma. They proposed that these defects may lead to gradual dehydration of the nucleus and lessen the resiliency and efficiency of the disk. This concept offers a possible explanation for degeneration of disks as a result of congenital imperfections and also as a result of trauma. Just how important a role is played by each is not yet clearly understood.

At present, all indications lead to a conviction that if one has intervertebral disks of perfectly normal integrity developmentally one will not be subject to herniation of a disk regardless of hard labor or injury to the back. The idea that a degenerating or herniating disk may be due to faulty development is not entirely new. For example, Echols [20] stated, "The fact that multiple ruptured disks are often found in cadavers suggests predisposing factors, such as degenerations or congenital imperfections of the disks."

The inadvertent passage of a spinal puncture needle into an intervertebral disk has been cited as a cause for degeneration of a disk.[21]

I do not feel that the evidence as presented in reports of cases has been conclusive. The sequelae of the type of trauma that has been inflicted on the disks of laboratory animals [8] are an entirely different matter and are not comparable to the type of trauma incident to a needle puncture in human beings. I have passed a spinal needle through the annulus a number of times when a disk was exposed at operation. The puncture wound closed tightly when the needle was withdrawn, and not a particle of nucleus tended to extrude. The wounds appeared so benign that it would require a great stretch of the imagination to believe that they might be cause for herniation. If at all likely, it would surely require a long time for the usual degenerative process to obtain. It is more likely that such a puncture wound would heal forthwith by first intention. Moreover, spinal punctures are commonly done and usually at a point higher than the common location of herniating disks. By far

20. Echols, D. H.: The Neurologic Aspects of Low Back Pain and Sciatica, J. A. M. A. **125**:416-420 (June 10) 1944.

21. Downing, F. H.: Collapse of Intervertebral Disc Following Spinal Puncture, U. S. Nav. M. Bull. **43**:666-673 (Oct.) 1944. Gellman, M.: Injury to Intervertebral Discs During Spinal Puncture, J. Bone & Joint Surg. **22**:980-985 (Oct.) 1940.

the majority of patients who present herniating disks have never had spinal punctures previous to the onset of symptoms.

In any case, before it is concluded that a spinal needle might be cause for degeneration and possibly herniation of disks, reports should be accompanied with incontrovertible proof, not only because of scientific reasons but because of the serious import and medicolegal implications.

IX. TERMINOLOGY

A. According to the Degree of Degeneration.—1. Grade 1 Degeneration: Grade 1 degeneration is an early stage of degeneration without herniation. The annulus fibrosus is eroded, weakened and thin enough to allow penetration of a bayonet forceps with moderate pressure, but it is not of "paper thinness." Macroscopic examination reveals definite degenerative changes in the nucleus pulposus, consisting in dehydration, partial sequestration and often a red, "inflamed," appearance. The specimen on the left in figure 6, taken from the fourth lumbar vertebra, is classified as grade 1 degeneration.

2. Grade 2 Degeneration: Grade 2 degeneration is an advanced stage of degeneration without herniation. In this case the annulus fibrosus is thin and has little resistance to pressure. A part or all of its posterior surface may be punctured with the tip of a bayonet tissue forceps or similar instrument, with no more resistance than a sheet of paper. The point of the forceps appears to sink into a soft nucleus without substance. The nucleus may be "mushy," or it may appear desiccated, stringy and fibrous. One has the impression that such a disk is on the verge of herniation.

The specimen on the right in figure 6, taken from the fifth lumbar vertebra, is an example of grade 2 degeneration, because of the almost complete erosion of the annulus in one location.

3. Grade 3 Degeneration: Grade 3 degeneration is an advanced stage of degeneration in which herniation, or rupture, of the annulus occurs. Figures 1, 4 and 7 illustrate grade 3 degeneration.

B. Extended Classification.—1. Herniating Intervertebral Disk: Any pathologic protrusion of a disk is classified as herniating intervertebral disk. The herniation is usually on only one side of the spinal canal and is thus designated as being on the right or on the left.

In about 7 per cent of the cases, the herniation extends clear across the spinal canal. These herniations are designated bilateral. They are often associated with symptoms and signs of compression of the nerve root on both sides.

In a small percentage of cases the herniation will be centrally placed and without sufficient protrusion laterally under the nerve roots to cause compression of the latter. Such an example is classified as central

herniation. These cases may be confusing when symptoms and signs are being evaluated. The patient usually presents the syndrome of degenerating disk without herniation. In a number of patients for whom the diagnosis of degenerating disk was made and in whom herniation was not suspected, this type of central herniation was unexpectedly found.

2. Ruptured Intervertebral Disk: If the annulus fibrosus is ruptured and a portion or all of the sequestrating nucleus is protruding through it, the disk is designated as ruptured. If the nucleus is completely sequestrated and can be pulled away in one piece, it is referred to as a ripe disk. If it is not completely sequestrated and it is necessary to use the curet, the disk is referred to as being green. It would naturally follow that all pathologic disks in which the nucleus pulposus is not completely sequestrated are green disks.

3. Pocketed Sequestration: If only a portion of the nucleus has undergone degeneration and sequestration and the rest of the disk appears normal, the lesion is called a pocketed, or partial, herniation, or sequestration. As already pointed out, patients who present this type of herniation are likely to give little or no history of pain low in the back. The symptoms and signs are related to only compression of a nerve root (see report of case of E. C., under section on operation).

4. Dissecting Herniation: In a small percentage of cases (2 to 3 per cent) in my experience, a sequestrated nucleus, instead of rupturing through the annulus, will dissect and inspissate itself upward or downward under the disk capsule (see report of the case of E. C., under section on operation). This is referred to as the dissecting type. The major portion or all of the extruded nucleus might be overlooked, especially if the operative exposure is not adequate.

5. Calcified or Ossified Herniation: Herniations that have been present for many years may have become surrounded by a lip, or cone, of bone. The sequestrated nucleus itself does not calcify, but spurs of bone from the margins of the vertebrae extend into the spinal canal above and below the herniation. The spurs may approach each other so closely as to almost encase the herniation. Until the spurs are chiseled or rongeured away, one may find it difficult to insert a curet between the vertebrae. The spurs contribute to the compression of adjacent nerve roots and should be removed. They may present in the lateral roentgenogram of the lumbosacral portion of the spine. An example of spur formation about a bulging annulus is demonstrated in figure 2, although the lesion was not a degenerating-herniating disk in the strict pathologic sense.

6. Herniation Within the Intervertebral Canal: The intervertebral canals are the channels through which the spinal nerves make their

exit from the spinal canal. In strict anatomic nomenclature they are referred to as intervertebral foramens, but the channels are of sufficient length that they might also be termed canals, and it is more appropriate in relation to this presentation that they be visualized as canals. An intervertebral canal is bounded superiorly and posteriorly by a pedicle and an inferior articular process respectively of one vertebra. It is bounded anteriorly by the body of that vertebra. The inferior boundary is formed partly by a superior articular process of the next lower vertebra and partly by the intervertebral disk between the two vertebrae.

Herniation strictly confined within the limits of the intervertebral canal deserves considerable attention. It may be rare, but it also may be present when the exploration has been considered noncontributory, because it has not been customary to explore the intervertebral canal. Inasmuch as this type of herniation relates to location or position of the herniation, it might well have been included under the heading herniating intervertebral disk, but I have purposely classified it as a separate entity to draw special attention to it. It is an obscure lesion and may be easily overlooked. At present its incidence cannot be evaluated, but I can see no reason from anatomic or pathologic standpoints why herniation could not occur within the intervertebral canal just as easily and as often as it does into the spinal canal. The fact that the majority of intraspinal herniations are laterally placed bears out this suspicion. Indeed, one should explore these lateral herniations carefully to make sure that they do not extend into the intervertebral canal. If such a herniation does extend into the canal, it would compress the nerve that is just cephalic to the one that is compressed by the intraspinal portion of the herniation.

I have recently uncovered three striking examples of ruptured disks with extrusion of nuclear material strictly confined to the intervertebral canal. The cases are described under the section on operation.

Recurrent Herniations.—I have encountered only 2 cases of undisputed recurrent herniations. In 1 patient a large right-sided herniation developed three months after a left-sided herniation was curetted away. Herniation was not present on the right at the first operation. At that time, curettement of the nucleus was not so thorough as is done now.

The second patient suffered a sudden extrusion of a completely sequestrated nucleus six years following the original operation. Six years ago a herniated disk was partially curetted, with complete relief of symptoms at that time.

Thorough curettement of the pathologic disk, while important in the consideration of possible recurrence, has not been emphasized so much in the interests of possible further herniation or recurrence as it has been in the idea of attainment of as complete a fibrocartilaginous fusion as possible. I do not believe that degenerating and sequestrating

nuclear material will incorporate itself satisfactorily into the development of the "fusion scar."

X. THE OPERATION

Indications.—The diagnosis of herniating, or ruptured, intervertebral disk in its usual location (below the fourth or fifth lumbar spaces or both) can be made with great accuracy from the history and clinical findings. In fact, experience in the past few years has taught that chronicity of symptoms, unilateral distribution and typical sciatic radiation of pain warrants the diagnosis of herniating intervertebral disk. Unless there is something unusual about the history and findings, myelograms with air and iodized poppyseed oil are unnecessary and might be even misleading if normal. Myelography with air or iodized poppyseed oil would be of no avail in the diagnosis of degenerating disk which has not herniated. This diagnosis must be made on the history and examination and chiefly the history. The myelogram would not indicate a herniation confined to an intervertebral canal.

Steindler's test with procaine hydrochloride may be used to advantage in differentiating reflex sciatic from radiating sciatic pain. Since it has been postulated that reflex pain down the lower extremity is not due to compression of a root but is reflected from a painful myofascial locus, the pain can be temporarily expunged by locally anesthetizing the myofacial locus (trigger zone). Not only is reflex pain and tenderness of the trigger zone relieved, but straight leg raising can be performed without pain. One may deduce from such positive results that the symptoms and signs may be due to a degenerating disk but not to a herniating disk. This situation should be made known to the patient because if he elects conservative treatment for a time it would not be so ill chosen as it would if he had a herniating disk. If the disk is herniating, the radiating sciatic pain would be due to compression of a root and would not be relieved by injection of procaine hydrochloride. In this case surgical treatment could be advised without equivocation. In cases, therefore, in which it is doubtful whether the degenerating disk has herniated or not, the test with procaine hydrochloride may provide the answer and fortify the surgeon for a more accurate approach to the problem and advice to the patient.

In an operative experience with 800 cases of herniating intervertebral disk and 42 cases of degenerating disk without herniation, the best results have been obtained with a thorough and complete operation which is outlined in the following paragraphs.

Procedure.—Since about 6 per cent of patients will have pathologic changes in the disks at both the fourth and the fifth lumbar spaces, it is advisable to explore both disks routinely. This 6 per cent applies to actual herniating disks at both places. A group of patients will present herniating disks at one of the two locations and degenerating disks at

the other. Another group will present degenerating disks at both places. No doubt many of the unsatisfactory operative results can be explained by the fact that one of these pathologic disks was unexplored and untreated.

The spinous processes of both the fourth and the fifth lumbar vertebra are removed. After the erector spinae muscles have been stripped from the spinous processes, one may grasp the latter with an instrument and determine the degree of fixation of the vertebra at that segment. When a degenerating disk is present, it is rather common to find that the adjacent vertebrae are not normally and solidly fixed. The laminal arches are scraped widely. The ligamentum flavum is then dissected from its cephalic laminal arch by a semicutting instrument. A tonsil dissector is a suitable instrument. The lower third of the fourth and fifth lumbar arches is rongeured away, the removal being carried equally wide on the two sides. The ligamentum flavum is then split in the midline to the dura. A blunt instrument is inserted between the ligament and the dura and held by an assistant while the ligament is removed as completely as possible on both sides. Finger palpation for the herniated disk is then done, but regardless of the impression the nerve root is retracted mesially and the disk is inspected. If the disk is herniated, or ruptured, it is easily disclosed by palpation or inspection. The first observation is that the nerve root is displaced posteriorly and comes into view quickly in the process of dissection. By means of a curved, blunt instrument the root is separated from the underlying lump and retracted mesially. This procedure may be difficult at times and requires care and patience because of an unusual adherence of dura to the herniated disk. If the nucleus pulposus has ruptured and is completely sequestrated (in which case it is referred to as a "ripe" disk), it can be grasped with a tissue forceps or hemostat and pulled in toto from its bed, and further operation on such a disk is unnecessary. If it can be established that a sequestrated portion of nucleus is "pocketed" and encased in a well formed capsule and the remainder of the disk feels of normal integrity, the latter is not incised or further curetted. If the annulus is or is not ruptured and the entire disk (nucleus and annulus) is soft and undergoing degeneration, then the annulus should be cut away as widely as possible with a sharp stab blade, much as one would plug a watermelon. The nucleus is then curetted away as thoroughly as possible. The nerve root on the opposite side is then retracted and the remainder of the annulus fibrosus cut away. All the remaining nucleus is curetted away. In making the exposure preparatory to retraction of the nerve root, one should dissect and remove the ligamentum flavum that lines the lateral wall of the spinal canal and rongeur bone as widely as possible without destroying the articular facets. This gives better exposure and thorough decompression and helps to obviate injury to the nerve root.

If the disk is not bulging or herniated, the operator should test the integrity of the capsule by trying to force the tip of his bayonet forceps through it. With reasonable force he will not be able to penetrate the normal capsule. If the capsule is thin and degenerated, the forceps will penetrate it and sink into an obviously soft nucleus.[22] Such a disk is curetted bilaterally as already described.

The wound is closed with tiers of interrupted silk, and a Penrose drain is left in place to be removed in twenty-four hours.

If it is necessary to treat only one disk, the patient is required to remain in bed two weeks. If it is necessary to curet two disks, he is required to remain in bed three weeks. This time is arbitrary but is certainly the minimum time required to assure that proper healing is well under way.

I have entertained the idea of placing fragments of bone in the disk cavity after the nucleus pulposus has been curetted away. The purpose is to stimulate actual bony fusion of the vertebrae if possible. This has been done in 4 cases, but sufficient time has not elapsed to draw conclusions. In each case, a whole spinous process was scraped of all tissue except periosteum. It was then crushed in several places and wedged into the intervertebral cavity. In a roentgenologic check-up of 1 patient three months after operation there was no evidence whatever of beginning ossification. If anything, it appeared that the fragment of bone was undergoing absorption. However, the idea is worthy of consideration, and more information will be forthcoming.

The postoperative course in my experience has not yet indicated the necessity of bone grafting as an additional procedure. I feel that the application of loose bone chips in the wound has little value in respect to the purpose intended and does add to the hazards of infection. I reexplored a patient recently in whose wound bone chips and fragments had been placed six months previously. The chips were resting as foreign bodies and in no way had aided in the solidification of the lumbosacral joint. I have felt that the application of casts has been rarely necessary. The lumbosacral portion of the spine appears to be sufficiently immobile of itself, so that two to three weeks in bed on a

22. Dandy (Concealed Ruptured Intervertebral Disks: A Plea for the Elimination of Contrast Mediums in Diagnosis, *J. A. M. A.* **117**:821-823 [Sept. 6] 1941.) has referred to this entity as a "concealed disk" but implied that it causes the same symptoms and signs as a herniating disk. This is true if the disk bulges enough under stress to compress the adjacent nerve root. The purpose of the present report is to point out that such a pathologic disk can be the cause of chronic pain low in the back without bulging and without compression of the root and can be adequately treated by operation. In a recent paper (Recent Advances in the Treatment of Ruptured [Lumbar] Intervertebral Disks, *Ann. Surg.* **118**: 639-646 [Oct.] 1943) Dandy has also stated the conviction that a "concealed disk" can be cause for pain low in the back without sciatic radiation.

properly fixed mattress and another one to two months of reasonable care will establish proper healing. Moreover, since the objective is the development of a fibrocartilaginous disk or scar in the place of the pathologic disk, the problem is somewhat different from that involved in the healing of a fracture of bone. In the event of extensive operation, such that the bony integrity of the spine is substantially weakened, bone grafting as an adjunct may become advisable. With the discovery of herniations in the intervertebral canals and other remote loci the scope of surgical treatment in this entity is broadened, and in some cases the proper and necessary operation involved may warrant tibial bone grafting or casting. It is not my purpose at this time to propose hard and fast rules concerning the principle of bone grafting as an adjunct procedure and certainly not to renounce it completely. In my experience, results have not indicated the necessity of supplemental grafting in the cases in which one disk has been curetted and the articular processes of the vertebrae have not been interrupted. The accessory procedure should not be done indiscriminately without consideration of the substantial increase in the magnitude of the operation, the element of time and the cost to the patient. Insofar as the laminectomy alone is concerned, the complete removal of as many as six or seven arches in numerous patients for various neurosurgical procedures has not been followed by evidence of instability of the spine, and bone grafting would appear superfluous. I feel that the matter is an open question and that each case should be determined on its own merits.

I feel that too much emphasis cannot be placed on the fact that small herniations, and particularly small extrusions of nuclear material, may be situated so far laterally in the spinal canal that they may be overlooked easily by palpation and may not be disclosed to inspection until the nerve root has been reflected mesially and down to its entry into the intervertebral canal. This type of exploration will necessitate removal of at least the cephalic half or perhaps all of a laminal arch laterally. The "dissecting type" of herniation may present the sequestrated nuclear tissue in this way in remote and obscure places and necessitate an extended thorough exploration to disclose and remove it. The following 2 cases illustrate the point particularly well.

E. C., a white man aged 67 years, was admitted to St. Joseph's Hospital on Oct. 28, 1945. He was a carpenter by trade. Three months before, at a time when he was physically at rest and not straining his back, he rather suddenly began to experience pain which radiated throughout the sciatic distribution on the left side only. He located the pain as coursing from a spot to the left of the sacrum, down the posterior aspect of the thigh and through the calf and involving the mesial half of the left foot and toes. He explicitly denied any history of pain low in the back either before or after the onset of sciatic pain. This was also his first experience of sciatic pain. The pain rapidly became so severe that he remained confined to bed until relieved by operation. All the signs

of compression of a nerve root were present except for the fact that the achilles tendon reflexes were equal.

At operation, a limited sequestration was disclosed at the fourth lumbar vertebra on the left. The annulus was ruptured, and an amount of sequestrated nucleus about the size of the rubber on a lead pencil was protruding through the defect and severely compressing the fifth lumbar root. The lesion was not disclosed until the cephalic half of the fifth laminal arch on the left was removed and the fifth lumbar root reflected mesially. The location of the rupture is shown in figure 9. It might have been easily overlooked had an extended search not been made. It would be a tragic circumstance to close a wound without finding the existing herniating disk that is responsible for the patient's complaint. Not only would the patient be unrelieved, but the diagnosis would remain obscure and one would be reluctant to reexplore. If the diagnosis of herniating disk is made, the surgeon should thoroughly explore every possible locus of herniation before pronouncing the exploration noncontributory.

The case just described illustrated clearly some other notable factors related to herniating disk. First, the sequestration was limited and was of a pocketed type, while the remainer of the disk was of good integrity. The patient experienced no pain, therefore, until the portion of sequestrated nucleus was extruded and impinged on the adjacent nerve root. He denied pain low in the back and described only sciatic pain. The syndrome was an acute one, and he was compelled to remain in bed, with unremitting pain from its onset until relieved by operation. The fact that the pathologic changes and their attending symptoms presented at the age of 67 for the first time is interesting and might favor trauma or wear and tear as the causal factor for the localized degeneration.

J. F., a white man aged 39 years, was admitted to St. Joseph's Hospital on Jan. 26, 1946. He had complained of pain low in the back for two years. Pain radiating in the sciatic distribution on the left side had its first onset spontaneously only two weeks before. Pain and paresthesia were referred to the small toe on the left as well as to the posterior part of the thigh and lateral aspect of the leg. Coughing aggravated the pain.

On examination all the findings related to herniating disk as described in this paper were present, including positive results from a straight leg raising test on the left and an absence of ankle reflex on the left. The knee reflexes were equal and active.

Operation.—On the definite diagnosis of herniating intervertebral disk a laminectomy was performed on Jan. 27, 1946. The fourth and fifth lumbar disks were explored thoroughly in the usual manner, but no herniation was disclosed at first in the spinal canal. The intervertebral canals at the fourth and fifth lumbar disks allowed the easy passage of a grooved director through them, so that it did not seem likely that there was a herniation in one of these canals. The findings on examination certainly were not those of herniation at a higher level. In fact, they rather definitely indicated an involvement of the left first sacral root. The usual inspection and mesial retraction of the first sacral root on each side revealed nothing abnormal, and, moreover, the annulus at both the fourth and the fifth lumbar vertebrae was firm and of normal toughness. An instrument passed upward to the second and third lumbar vertebrae extradurally met with no obstruction. The situation was indeed incredible. Since there

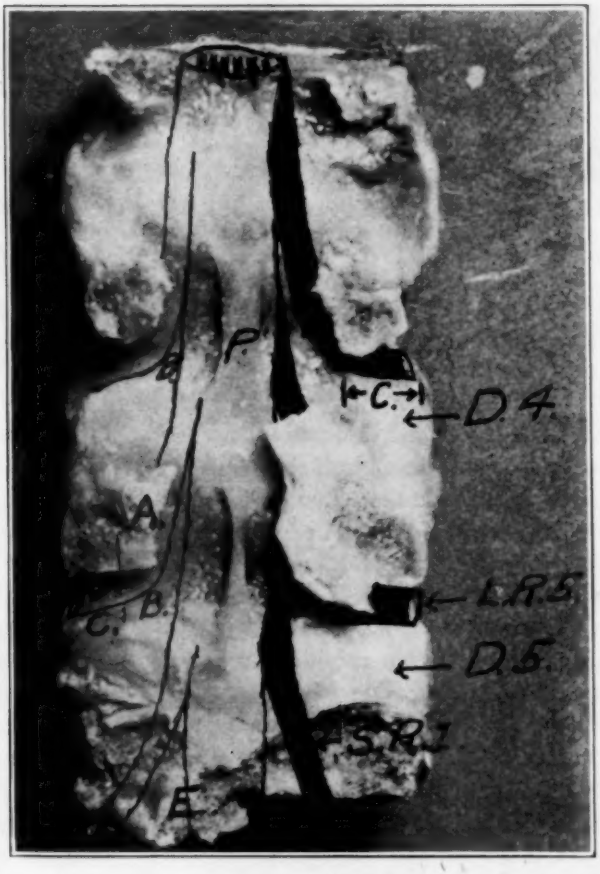

Fig. 9.—Semidiagrammatic sketch to illustrate unusual loci for herniations of disks. The photograph was taken of the specimen used in figure 3. The laminal arches and ligamenta flava have been largely removed to expose the spinal canal. The dura and nerve roots have been drawn in.

The limited or pocketed nuclear sequestration described in the case of E. C. had dissected downward under the annulus of the fourth dorsal space and presented at point *A*, compressing the fifth lumbar root on the left. Such sequestrations may dissect upward and present at point *B*. The sequestrated nucleus in the case of J. F. presented at locus *E* on the body of the first sacral vertebra. These limited lesions may be overlooked if exploration is not thorough. Inasmuch as the nerve root is fixed and contained in a limited space at these loci, a small amount of extruded nucleus will compress it severely.

Experience with lesions such as these raised the question of the possibility of herniations, or ruptured sequestrations, within the confines of the intervertebral canal, such as at locus *C*. The locus marked *C* at the fourth lumbar disk on the right represents the location of the rupture in the case of J. W. The rupture and nuclear extrusion were strictly confined within the intervertebral canal.

Note how the posterior longitudinal ligament (*P.*) bridges over the vertebral body and fans out over the intervertebral disk.

D. 4 and *D. 5* indicate the fourth and fifth lumbar intervertebral disks, the fifth being the last, since there are no intervertebral disks between the sacral segments. *L. R. 5* indicates the fifth lumbar nerve root and S. R. *1* the first sacral root.

could be little question about involvement of the first sacral root, the laminal arch of the first sacral vertebra was removed and an amazingly large extruded nucleus presented. The sequestrated nuclear material had been extruded from a pocket in the center of midsagittal plane of the fifth lumbar disk and had dissected caudalward under the annulus to present over the body of the first sacral vertebra. The nucleus rested in a shallow excavation on the body of the first sacral vertebra and compressed the first sacral root on the left at the place where it entered the first sacral canal (see figure 9, locus *E*). The extruded nucleus was easily pulled away in one piece. The lesion might have been easily missed and the exploration thought to have been complete.

In figure 9 I have marked loci where obscure lateral or dissecting herniations may be found.

Extended Exploration for Herniation in an Intervertebral Canal.—This subject is purposely treated under a special heading in order to add the special emphasis that it merits. After I had been confronted with herniations in an extreme lateral position, the question arose concerning the possibility of a pocketed type of sequestration and rupture within an intervertebral canal itself. This should be given consideration when the diagnosis of compression of a root seems clear and no herniation is found within the spinal canal.

The first patient (J. W., to be described) in whom I disclosed a definite herniation of this type was operated on in December 1945. In the following month, being fortified sufficiently with the newly gained knowledge to carry my exploration into the intervertebral canals, I encountered 2 more striking examples of cases of this kind. In 1 of the patients a partially extruded nucleus presented at both the fourth and the fifth lumbar intervertebral canals on the left. In these 2 additional cases, those of A. H. and W. Van C., an intraspinal exploration, however thorough, would have completely failed to disclose the pathologic change and causal factor for the sciatic pain. It was not until the intervertebral canals themselves were exposed that the lesion presented itself. Moreover, the spinal decompression alone could not have conceivably relieved the compression of the nerve root. After the experience with these 3 patients I am convinced of the strong probability that this heretofore obscure type of herniation yet resides unrelieved in some patients who have had so-called negative explorations. In the past three years I have operated on 2 patients who presented definite herniating disk syndromes with all the positive signs of compression of nerve roots, including an absence of the achilles tendon reflex on the painful side. A thorough intraspinal exploration failed to disclose a herniation or satisfactory explanation for the symptoms and signs of the compression of the roots. The patients were not relieved of their complaints and are being recalled for the purpose of the exploration of the intervertebral canal or canals in question. At the present time the following pertinent and informative statements may be made in reference to the herniation of the intervertebral canal.

1. A herniation, or rupture, can occur only in the intervertebral canal that is cephalic to the pathologic disk. The intervertebral disk forms the caudal boundary of the pair of intervertebral canals that lies just cephalic to the disk, but this same disk is not related to the intervertebral canals that lie caudal to it. Hence, in a normal anatomic situation the first sacral nerve root is not subject to compression by a herniation confined in an intervertebral canal.

2. A herniation confined within an intervertebral canal will compress the nerve root in that canal. Thus a herniation of the intervertebral canal from the fifth lumbar disk will compress the fifth lumbar nerve root. One from the fourth lumbar disk will compress the fourth lumbar root and may cause signs that would lead to a suspicion of an intraspinal herniation at the third lumbar disk, namely, hypalgesia in the fourth lumbar distribution and a diminished patellar reflex, while the achilles tendon reflexes remain equal. If a herniation, or rupture, is intraspinal and extends also into the adjacent intervertebral canal, say at the fourth lumbar space, it may compress both the fourth and the fifth lumbar root and thereby cause diminished patellar and achilles tendon reflexes on one side, with noticeable weakness of the ankle. Hence, if signs of involvement of the fourth lumbar root are present, it does not necessarily follow that a herniation must be as high as the third lumbar disk.

3. The fact that the intraspinal aspect of the annulus fibrosus proves to be of normal firmness and integrity does not rule out the possibility of a herniation in the intervertebral canals just above it. In all 3 of the cases described in the following material the intraspinal aspect of the pathologic disks appeared normal, and the annulus in each instance was of normal toughness. It so happened that in these 3 cases the nuclear sequestration was of a partial or pocketed type, and hence no clue to the likelihood of herniation in the intervertebral canal was provided by a general degeneration of the disks. It is, of course, conceivable that in other cases the defective disk will betray itself by a more extensive degeneration and annular erosion in its intraspinal aspect.

4. At present I feel that one can deduce some information relative to the possible presence of a herniation in an intervertebral canal by attempting to pass a suitable instrument through the latter. Such an instrument should be devised exclusively for this purpose and be of such a caliber as to pass through the unobstructed canal with relative ease. Thus far a grooved director, properly bent, serves the purpose reasonably well. In patients A. H. and W. Van C., described later, this instrument was passed with ease through normal canals and met with definite obstruction where herniations were present.

5. The intervertebral canal may be unroofed and exposed partly with suitable rongeurs and partly with chisel and mallet. Thus far I

have found it necessary and advisable to remove the inferior articular process or mesial facet of the vertebra, the canal of which is being explored.

6. Myelography with iodized poppyseed oil, Pantopaque or air would obviously be of no diagnostic value in the visualization of the presence of herniation of an intervertebral canal.

7. Under the section devoted to the roentgenogram, some comments were made concerning the narrowed or collapsed disk. Two cases were cited in which the roentgenograms revealed completely collapsed disks, but no intraspinal herniation was found at exploration. The patients were relieved by decompression of the corresponding intervertebral canals. At that time my decompression of the intervertebral canals was not complete. It consisted largely in widening of the intraspinal orifice of the canal and may not have been of sufficient scope to have brought a possible intracanalicular herniation into view, especially since my attention was not directed to a possible herniation at this locus. Hence, in such cases the possibility of herniation of an intervertebral canal has not been entirely cleared. Knowledge concerning these matters is still in the formative stage.

REPORTS OF CASES OF HERNIATIONS OF THE INTERVERTEBRAL CANAL

J. W., a white man aged 62 years, was admitted to St. Joseph's Hospital on Dec. 13, 1945. He described pain low in the back with typical sciatic radiation on the right, to and including the foot. He dated the onset a year before, following a strain on the back while he was roping a steer. He presented all the significant symptoms and signs of herniated disk but also presented a diminished knee jerk on the right. The roentgenogram showed rather narrow intervertebral spaces but otherwise nothing of special note.

A laminectomy was performed on Dec. 14, 1945. The annuli at the fourth and fifth lumbar disks were bulging into the spinal canal somewhat but were firm and of normal integrity and did not appear to account for the symptoms. While the fourth lumbar disk on the right was explored, a bit of nuclear material could be seen in the entrance of the adjacent intervertebral canal. Ultimately, that entire canal was opened, and a surprising amount of sequestrated nucleus was found to be jammed into the canal, severely compressing the fourth lumbar root (see figure 9, locus *C*, at the fourth lumbar disk on the right, and see figure 10). The portion of the annulus which forms the inferior boundary of the intervertebral canal was ruptured, but the rupture did not extend into the spinal canal.

A. H., a white man aged 56 years, was admitted to St. Joseph's Hospital on Jan. 17, 1946. He had experienced some pain off and on in the sciatic distribution on the left for about twenty years. It became severe rather suddenly about eight years before, when he was reaching for a high shelf. He traced the course of the pain from a point to the left of the sacrum down the posterior aspect of the thigh. Pain was absent in the knee but was felt in the lateral aspect of the leg, the heel and across the top of the foot. He had never sensed pain in the right lower extremity. Pain on the left was aggravated by coughing and sneezing. For

years he had had considerable difficulty in resting at night because of the pain. Getting on his feet in the morning was an ordeal, and of late moderate activity had caused the pain to become intolerable. Function of the bowels and bladder was unimpaired.

The significant findings on examination were as follows: There was almost no lordotic curvature of the lumbar portion of the spine, but the latter presented a mild scoliosis to the left. The erector spinae muscles were extremely spastic on both sides. Forward bending to about 50 per cent of the normal maximum excited sciatic pain on the left. Patrick's maneuver caused no pain on either side, but straight leg raising was painful on the left. Moderate pressure over the spine of the fifth lumbar vertebra and over the left loin was uncomfortable, and the region of the sciatic nerve in the left thigh and the left calf was tender compared with those regions on the right side. There was a definite hypalgesia in the fifth lumbar distribution on the left. The patellar tendon reflexes were equal and

Fig. 10.—Photograph of sequestrated nuclear material removed from the fourth lumbar disk in the case of J. W. The rupture of the annulus and nuclear extrusion were strictly confined within the limits of the intervertebral canal on the right (see figure 9). The upper piece of tissue was completely sequestrated and jammed into the intervertebral canal, severely compressing the fourth lumbar root in the canal. The pieces of tissue in the lower half of the photograph were removed from a pocket within the disk.

This finding introduces a new possible location for herniation and ruptured disks, which to my knowledge has not been heretofore given attention. Such an obscure lesion may account for the persistence of symptoms after so-called negative explorations.

active, but the achilles tendon reflex was absent on the left. The abdominal, cremasteric and plantar reflexes were normal.

Roentgenograms of the lumbosacral portion of the spine revealed arthritic spurs on the margins of several lumbar vertebrae. The lumbosacral articulation in particular showed pronounced hypertrophic arthritis, with condensation of the opposing surfaces of the vertebra and the sacrum. The lumbosacral joint space was abnormally narrow. The sacroiliac articulation on the right showed hypertrophic arthritis in its lower aspect, with narrowing of the joint space and condensation of the opposing surfaces.

(NOTE: As pointed out in the chapter on the roentgenogram, it is not inconceivable that spurs and condensations about the low lumbar, lumbosacral and sacropelvic joints could be reactions to excessive strains and stresses that are themselves attributable to pathologic changes of the intervertebral disk and weakness.)

A definite diagnosis of herniating intervertebral disk was made.

Operation.—On Jan. 18, 1946, with the patient under anesthesia induced with tribromoethanol, the fourth and fifth lumbar intervertebral disks were explored in the usual manner. Pocketed sequestrations of nuclear tissue were found in the intervertebral canals at both the fourth and fifth lumbar disks on the left. The ruptures were confined within the limits of the intervertebral canals, and sequestrated nuclear tissue was jammed against the fourth and the fifth lumbar roots in their respective canals. Both canals were completely exposed by removal of the inferior articular processes of the fourth and fifth lumbar vertebrae that form the dorsal boundaries of the canals.

The wound was closed as heretofore described without bone graft or application of a cast. After this amount of operation it is at present felt that the patient should remain in bed for three weeks. The necessity of grafting or casting is at present an open question. The patient sensed immediate relief of his acute pain on awakening from the anesthesia and at the present writing is up and about, with no significant complaints.

W. Van C., a white man aged 37 years, was admitted to Mercy Hospital, Denver, on Jan. 27, 1946. He had complained of pain low in the back for six years. One year before pain began to radiate down the left sciatic distribution, associated with a numb feeling in the left leg. There was no pain referred to the right lower extremity. Coughing and sneezing aggravated the pain, and pain in the left hip was aggravated at the time of bowel movement. For the past two weeks he had been confined to bed with acutely severe sciatic pain, which followed some hard work in the cornfields.

On examination the patient presented all the positive signs as outlined in this paper as related to herniating disk except for the following unusual ones: There was hypalgesia in the fourth lumbar distribution on the left, and the left knee, or patellar, reflex was definitely diminished. The achilles reflexes were equal.

Operation.—Because of the findings on examination, the third, fourth and fifth lumbar disks were examined. There was a partial degeneration of the nucleus and annulus of the third disk on the left, such that the annulus was almost completely eroded in an area about 0.25 cm. in diameter. There was no herniation at this level, however, and exploration of the intervertebral canal on the left at this level revealed no herniation. A block containing the eroded annulus was cut out and the degenerated nucleus thoroughly curetted away. The intraspinal aspect of the disks at the fourth and fifth lumbar spaces was normal, and the annulus at both places was of normal firmness. However, after complete exposure of the intervertebral canal at the fourth lumbar disk on the left, it was noted that the intracanalicular portion of the fourth lumbar nerve was displaced dorsalward. It was not until this portion of the nerve was reflected dorsalward and mesialward that a large piece of sequestrated nucleus was uncovered. It fairly popped out of a pocket which had ruptured within the confines of the intervertebral canal, and the remainder of the disk was of normal integrity. The severe compression of the fourth lumbar root in its canal on the left accounted for the hypalgesia in the fourth lumbar distribution and for the diminished knee jerk without diminution of the ankle jerk. The patient was completely relieved of the sciatic pain on awakening from the anesthesia.

XI. POSTOPERATIVE CARE

Throughout this thesis it has been difficult to separate sharply the degenerating from the herniating disk in respect to surgical considerations. Since the herniating, or ruptured, disk is only an advanced stage of the degenerating disk, the problems involving operation and postoperative care are essentially the same. Treatment involves three essential objectives: (1) relief of compression of the root if it exists, (2) stabilization of the lumbar or lumbosacral joints and (3) release and relaxation of spastic muscles about the lumbosacral region and restoration of strained ligaments.

Relief of compression of a root is simple enough and is the easiest part of the contract.

Stabilization of the lumbosacral portion of the spine is contingent on the development of a firm fibrocartilaginous scar which fixes the adjacent vertebral bodies (see section on pathology).

Relaxation of spastic muscles and restoration of strained ligaments and tendons may require persistence and patience. Toward this end the maintenance of the lordotic posture is important. Boards are placed crosswise under the mattress so as to lift the patient in a manner that will support the small of the back, and the patient is encouraged to sleep on his back for the most part. This is a simple but, I feel, an essential part of the treatment. Almost every patient whom I have treated has agreed, without reservation, that this arrangement has been greatly beneficial to him, and those who have attempted to discard it have readopted it of their own volition. Many patients even before operation have discovered for themselves that sleeping on the floor is preferable to sleeping on a mattress. A patient with a weak back should divorce himself forever from the soft, downy mattress on which a partially flexed posture is assumed. The extended posture with emphasis of lordosis of the lumbar region releases tension on the ligaments, muscles and tendons of the lumbosacral portion of the spine and breaks the cycle of spasticity, deformity and irritability. Just because herniation of a disk has been treated surgically and the compression of the roots relieved, the tangible objective, it does not follow that these long-standing reactionary factors will immediately abate. This third phase of the treatment is paramount in the obtaining of optimum results. In cases in which chronic pain low in the back is a part of the syndrome, the patient should have check-up examinations at intervals of about one month after the operation until maximum improvement has been attained. He should be cautioned continually to adhere to the prescription, because it seems normal for the average patient to "forget" or to "misunderstand" the directions. Neither the doctor nor the patient need be disheartened if recovery is delayed for periods as long as eight months to a year. The patient should be reassured and the purposes and objectives of the

treatment explained in terms that he can grasp, because in any long-continued treatment that seems slow in attaining success it is only natural for the patient to lose faith. It is part of the treatment to proffer periodic reassurance and rechecking in order to keep the patient from deviating from the prescription. These remarks concerning postoperative care relate, of course, to cases of advanced and severe herniating disks. Many patients, especially those who have simple and limited herniated disks, never feel that it is necessary to have the first check-up examination. There is obviously a complete gamut of variations in respect to the extent of the pathologic changes and to the element of time in response to treatment. If optimum results in the management of the pathologic disk are to be uniformly attained, then it is certain that the patient who has had a ruptured disk cannot always be sent on his way as cured because the wound is healed and he is free of fever.

The manner in which the mattress is adjusted merits emphasis, because the wrong adjustment may be harmful. Boards 1 inch (2.5 cm.) by 6 to 10 inches (15 to 25 cm.) are suitable. Leaves from the dining table are often convenient. The mattress should preferably have no inner spring. The board should be placed directly under the mattress and crosswise, so that the ends rest on the sideboards of the bed. Sometimes two or three boards on top of one another are necessary, depending on the mattress, to obtain the proper-sized hillock or smooth ridge across the mattress. This ridge should be only wide enough to accommodate the curvature of the lumbar region and high enough to lift the lumbar portion of the spine a little and maintain lordosis of the lumbar region that is moderately exaggerated for the individual patient. There should be no sharp ridges that are uncomfortable. The ridge should not be located under the hips or under the chest or costal margins. This not only defeats the purpose intended but provokes other postural pains in the back and hips.

Some patients have been discharged from the hospital completely free of their former pain of herniating disk only to call after two or three weeks and complain of what they think is a return of the old trouble. A visit to the home reveals that instructions have not been carried out, and examination reveals what I refer to as a "spastic back," without the description or findings of pain from compression of a root. The patient maintains a somewhat flexed posture and is reluctant to extend his back. The erector spinae muscles are spastic, and there is usually tenderness parasacrally. It is the picture of tendinomuscular pull or strain. Appropriate muscles of the back become spastic in an attempt to splint the lumbar and lumbosacral segments. Rest in bed for a few days or a week on a properly fixed mattress, providing a hillock under the small of the back and occasionally a 10 pound (4.5 Kg.) traction to each leg, has given complete relief. Heat is a

valuable adjunct. Such a postoperative complication is in such a case again due to an insufficiently stable joint. After thorough curettement of a disk, I feel that the patient should remain in bed for an absolute minimum of two weeks, and it should be remembered that dependable fusion and firm intervertebral fixation probably require about two to three months. Casts or other external fixation or tibial bone grafts are rarely necessary. The scar will form, and fixation will obtain though the patient is ambulatory, and when the policies given here have been observed the results have been good.

Some patients who have severe herniating disks will continue to complain of some residual sciatic pain after operation. This is not surprising when one witnesses the swollen inflammatory state of the compressed nerve root, but if the operation has been thorough this residual sciatic pain will disappear with time. Subjective numbness in the distribution of a nerve root may last indefinitely and is due to loss of fibers of the sensory root. The patient should be apprised of the difference between numbness and pain.

A certain amount of stiffness of the lumbosacral portion of the spine is a natural consequence of the operation and is the objective that is bargained for. An intervertebral disk that is a fibrocartilaginous scar is certainly not so mobile as a normal disk, but relief of the patient's discomfort is contingent on stabilization and immobilization of the joint.

Pain low in the back and sciatic pain incident to pathologic changes in the intervertebral disks can now be adequately and satisfactorily treated, with good results, but the situation is not foolproof. Patience and understanding of all the factors involved are paramount to the best results.

If the operation is thorough and the wound is given a chance to heal well and escapes infection, braces and belts are not to be encouraged except in rare instances. Strange as it may seem, the back is not weakened by the operation described but strengthened considerably more than it was previous to operation. The relief of chronic pain low in the back and the episodes of acute pain bear out this statement.

XII. RESULTS

Industrial Implications.—When the surgical treatment of degenerating and herniating disks is carried out as outlined, the results on the whole are highly satisfactory. However, when speaking in terms of results, one should have clearly in mind the type and degree of pathologic changes in the disks that exist in the individual case. Broadly speaking, one can visualize the degree or extensiveness of disintegration as ranging from small pocketed sequestration, on the one hand, to disintegration of the entire disk, on the other. In the first case, the symptoms and signs may be only those of compression of a root and its attending sciatic radia-

tion. There is usually no complaint of chronic pain low in the back. When the compression of the nerve root is relieved by elimination of the small herniation in these cases, this being done either by minimal or by maximal exposure, the results are not infrequently 100 per cent. These are relatively simple cases. The indications are clear, the surgical problem is not difficult and relief is usually immediate. The situation is not complicated by an unstable intervertebral joint. On the other hand, when one is dealing with advanced degeneration of the disk as a whole, with or without herniation, the problem is considerably more involved. The patient should remain in bed longer after operation and should avoid heavy labor for a longer period. Such patients will usually complain of chronic pain low in the back which has existed for years, augmented from time to time by acute "toothache-like" pain deep in the gluteal region. One might alleviate compression of a root and true sciatic radiation, if it exists, in short order, but one cannot reasonably expect to abolish the factor of pain low in the back without time, patience and an understanding of the objective to be gained. The development of a good scar that adequately fixes adjacent vertebrae requires at least two to three months and even longer in many cases. During this time, the extended posture of the lumbar portion of the spine should be maintained while the patient is in bed and out and strain on the back should be avoided. Patients in these cases almost uniformly feel great relief while in bed and at the time they are discharged from the hospital. The greater percentage continue to do well, and strong backs develop. Some are not so careful and fail to observe the rules. They may experience further episodes of acute pain. They yield to treatment, however, and in time, as the lumbosacral joint grows stronger, the acute episodes cease to occur and the residual pain low in the back fades away. In 5 cases of severe herniated disks I have prescribed a steel stay corset as an aid in partially immobilizing the lumbosacral portion of the spine and maintaining correct posture. I feel that this is an advantage for a few patients who, for economic reasons, would like to return to work at an early date, if the type of work would not be too encumbered by the corset.

It is true that if a patient with an acute pain low in the back of the type under discussion is put to bed with extension of the lumbar region and with or without traction for a week, he, too, will usually feel relieved without operation. The basic cause has not been remedied, however, and he is subject to the same repeated cycles of pain. The objective of operation is to establish a satisfactory permanent stabilization.

These remarks are intended as explanation and not apology for the fact that results in such cases may at first seem poor. It is a rare patient who does not bear good affidavit for his treatment after six months. Also, as might be expected when such severe lesions are being dealt with, few patients can be classed as 100 per cent relieved. The greater

percentage will be 60 to 90 per cent relieved. I have had patients say with profound gratitude that they are able to get a comfortable night's rest for the first time in years or are able to sit for long periods or stoop and otherwise put their backs to test without paying heavily the price of gnawing and aching pain low in the back.

Considerable criticism is yet extended by some in respect to the merits of operation on even the profound herniating disk. I feel that physicians—not the patient—have perhaps expected too much in terms of results. It is strange that it is so, because previous to 1934 a patient with herniating disk and incapacitating and agonizing sciatica went without the specific treatment that he can be given now. He was a victim of "shots in the hip," stretching of the sciatic nerve, injections of procaine hydrochloride, isotonic solution of sodium chloride and alcohol into the sciatic nerve, repeated epidural or parasacral injections of procaine hydrochloride or periods of hospitalization for bed rest, traction and similar treatment, all of which were obviously of little avail as a cure. A patient with proper surgical treatment of a herniating disk now bears the only testimony that is needed. Assuming that he were only 50 per cent relieved, I—and I know the patient—should consider the relief a real achievement.

The degenerating-herniating disk is a serious lesion and should be deserving of the same consideration as that given to the dislocation of a major joint or fracture of a long bone. One could hardly expect, after the most expert surgical treatment, to reduce uniformly the disability of a patient to zero or that an enlisted man could withstand the rigors of modern military training. With this, as with any other major surgical problem, the relief of illness and pain is the first objective. Physical and industrial rehabilitation is the second.

The herniating disk has become of considerable medicolegal and industrial import. Matters relating to the etiology and to the so-called specific accident which is thought to be responsible for the injury to the disk cloud the issue in respect to liability and compensation. Often the correct diagnosis is not made until the time limit (according to the statute of limitations) from the "specific accident" has passed. This relieves the insurance company of liability and places the patient at a disadvantage. In the state of Colorado, if I am correct, these problems have been obviated to some extent for the present by a ruling that even though a pathologic disk may have preexisted an acute attack of pain while in the line of duty constitutes an aggravation of the condition and renders the insuring company liable. In view of the specialized nature of the syndrome and the reasonable likelihood that the correct diagnosis may be long overlooked through no fault of the patient, the problem of reopening the case after the time limit has expired becomes a pertinent one.

In my experience with industrial cases I have felt that the patient's disability has ultimately been reduced from almost total disability to 5 or 10 per cent in most of the cases. Some stiffness of the lumbosacral portion of the spine usually persists, and it is a result that is intended. It is usually of such a degree as to constitute, in my opinion, a 5 per cent disability for at least a year.

XIII. SUMMARY AND CONCLUSIONS

Evidence has been presented to substantiate the proposition that degeneration and disintegration of the intervertebral disk in the low lumbar region is the predominant cause of chronic pain low in the back. Herniation and rupture of a disk is an advanced stage of degeneration and is associated with the syndrome of compression of a nerve root. The process of degeneration of the nucleus pulposus and annulus fibrosus described is a necessary prerequisite to herniation and may prove to be, for the most part, of developmental origin. Whatever role trauma may play, it is only an accessory one.

The syndrome of chronic pain low in the back is due to a weakened lumbar or lumbosacral joint. The syndrome of radiating pain in sciatic distribution is due to compression of a nerve root. These two syndromes are separate and distinct entities. They are due to different aspects of the same pathologic process and hence may exist independently or combined.

Treatment of the degenerating disk consists in removal of the pathologic tissue. The result is contingent on the development of a new fibrocartilaginous disk that serves to fuse the adjacent vertebrae into a mechanical unit.

There are a number of different types of herniation which have been classified and given separate consideration. Special emphasis is placed on herniation within an intervertebral canal—a disclosure that broadens the variety of pathologic changes in disks and widens the scope of operations.

632 Republic Building.

ACUTE SUPERIOR MESENTERIC ARTERY THROMBOSIS

Recovery Following Extensive Resection of Small and Large Intestines

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WHILE I was on duty at an evacuation hospital functioning in February 1945, amid the rush of caring for battle casualties it was interesting to be confronted with an unusual acute condition within the abdomen which required operation.

An infantry private first class, 19 years old, was admitted to the hospital on February 16, with shell fragment wounds of the left arm and right thigh. Shortly after admission these wounds were excised, with the patient under anesthesia induced by pentothal sodium. A foreign body was removed from the wound in the right thigh. The patient made an uneventful recovery and was out of bed on the third day. He was scheduled to be evacuated to an Army convalescent hospital on the fourth day after operation.

On the evening of the third day, shortly after eating his evening meal, the patient was seized with severe pain in the upper abdominal region. He vomited, and diarrhea developed. The vomiting continued all evening. The temperature and pulse were normal. The blood count, taken around midnight, revealed a white blood cell count of 17,000, stab forms 10 per cent, polymorphonuclear leukocytes 81 per cent, lymphocytes 6 per cent and monocytes 3 per cent. Physicial examination revealed a soft but tender abdomen. There was no localized point of tenderness. The severity of the pain was out of all porportion to the physical signs. After observation by the surgical team on duty in the ward, morphine hydrochloride, ¼ grain (0.01 Gm.) was given hypodermically. There was no relief of pain. Early the next morning I was called to see the patient. The temperature and pulse were still normal, but on physical examination there was some bilateral rectospasm and tenderness in the midabdomen. There was no tenderness over McBurney's point. Both of the inguinal grooves were soft and not tender. The blood cell count was now white blood cells 22,300, stab forms 17 per cent, polymorphonuclear leukocytes 72 per cent lymphocytes 8 per cent and monocytes 3 per cent. Results of examination of the chest were normal. The urine was normal except for rare red blood cells, occasional casts and sulfa-like crystals. The patient had been receiving the routinely given sulfadiazine.

The case was considered one of an acute condition within the abdomen, with a differential diagnosis of possible perforating gastric ulcer, acute cholecystitis, volvulus or mesenteric artery thrombosis. It was not considered to be acute appendicitis. The vomiting had persisted.

A roentgenogram of the abdomen with the patient in the erect posture was ordered. This showed no evidence of free gas under the diaphragm. The

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temperature had risen to 100.2 F. The pulse rate was 120, and the respiratory rate was 36. Exploratory laparotomy was indicated.

Operation.—The operation was started with the patient under spinal anesthesia induced by 150 mg. of procaine hydrochloride. Because of the findings, the anesthetic was changed to general open ether with endotracheal tube.

Findings.—A right rectus incision was made. The peritoneal cavity contained a moderate amount of clear fluid. The presenting small intestines were dark blue-black but were not distended. There was a pronounced gangrenous odor. The incision was lengthened upward and downward. There was no evidence of volvulus. The approximate upper 20 inches (51 cm.) of the jejunum was viable, and pulsation of the arteries could be seen as they passed from the mesentery into the jejunum. At a point about 20 inches from the fossa of Treitz, the pulsation of the arteries suddenly ceased and the color of the intestine changed just as abruptly. Following the mesentery down toward the right iliac fossa, all the arteries were pulseless. The mesentery was without fat, and all the vessels could be seen readily. Passing down the jejunum and ileum, one quickly observed that all the small intestines were blue-black. Surprisingly, the appendix, cecum, ascending colon, hepatic flexure and beginning of the transverse colon were also found to be blue-black. The ileocolic and right colic arteries with their branches were pulseless, but near the midtransverse colon the color of the colon became pink and good pulsation was visible. Here again there was a sharp line of demarcation between the viable and the necrotizing colon. The midcolic artery was found to be pulsating well. With these findings, a diagnosis of thrombosis of the superior mesenteric artery just below the origin of the midcolic artery was made. The mesentery was filled with greatly enlarged, soft lymph nodes.

Procedure.—It was realized that only about 18 inches (46 cm.) of the upper jejunum would remain after resection of necrotic small intestine and also that all the large intestine up to the midtransverse colon would have to be resected. However, there was no choice, and radical excision was indicated. Naturally, I feared that not enough bowel surface would remain for digestion and absorption. It was realized that inanition might ensue. Technically the resection was simple. On division of the mesentery near its root, the thrombi could be seen within the lumen of the vessels. The jejunum was divided and both ends closed; the proximal end was inverted. The transverse colon was divided and both ends closed and the distal end inverted. The entire necrotic bowel was removed in one mass. An isoperistaltic, side to side jejunocolostomy was performed. The aperture was about 1½ inches (4 cm.) long. The suture line was reenforced by the placing of the omentum over it. The denuded surface in the right inguinal groove was peritonealized. Five grams of sulfanilamide powder was introduced into the right side of the peritoneal cavity, which indeed seemed empty. The abdomen was closed with through and through silk sutures, and the rectus sheath was closed with interrupted chromic surgical gut sutures. The skin was closed with interrupted silk sutures.

Specimen.—Unfortunately, with the volume of battle casualties (eight operating tables were functioning at the time), the specimen, because of its bad, gangrenous odor, was put into the potbelly stove and burned by the operating room sergeant. Therefore, the opportunity of carefully examining it and removing a node for pathologic examination was unfortunately lost.

Postoperative Course.—A Levine tube was passed into the stomach, and Wangensteen suction was applied. Penicillin and sulfadiazine were given for

the first three days. The patient stood the operative procedure well. Medicaments, 5 per cent dextrose in isotonic solution of sodium chloride and 10 per cent dextrose in distilled water in the ratio of 2:1, were administered intravenously. Thiamine hydrochloride was also given. Two transfusions of 250 cc. of whole blood were given. After each transfusion the patient had a fever reaction. Therefore they were discontinued. As soon as it was ascertained that the anastomosis was functioning well, the Levine tube was removed and feedings were started. Just as soon as some solid food and fluids were given, the patient complained immediately that his bowels had to move. The fluid seemed to run right through the remaining intestines. The patient therefore insisted on remaining on the bedpan for long periods. He was afraid to get off of the bedpan. A colonic tube was then left in the rectum and drained into a container on the ground.

It was felt that the patient might benefit by the intravenous use of casein hydrolysate and thiamine hydrochloride (vitimin B_1), 10 mg.; riboflavin (vitamin B_2), 5 mg.; nicotinic acid, 20 mg.; and ascorbic acid (vitamin C), 100 mg. daily. Only thiamine hydrochloride and ascorbic acid were available and therefore employed.

During the convalescence at our hospital the patient coughed and expectorated a great deal of thick phlegm. Physical examination, corroborated by roentgenologic examinations, revealed some evidence of atelectasis or infarct of the right lower lobe of the lungs. With encouragement of coughing, deep breathing into a paper bag and frequent change of posture, this condition improved.

Five days after the operation the hematocrit level was 32.8 per cent, the hemoglobin content 11 Gm., and the total protein content 6.5 Gm. per hundred cubic centimeters. The protein intake was kept up by the use of plasma intravenously. The fluid balance was also carefully maintained.

History.—When the patient had improved sufficiently, a careful history was obtained because of the interesting and unusual findings.

Family History: There were four siblings. The mother and father were healthy and well. There had been no operations and no serious illnesses.

Habits: The patient smoked one package of cigarets a day and used no alcohol or drugs. He was married just before he entered service. He denied having venereal disease. He had had the usual childhood diseases. By occupation, he was a truck driver and defense worker and worked with molten metal.

Systems: Neurologic examination showed that occasionally he felt light headed. There was no history of fainting, convulsions or paresthesias, but he had had occasional headaches. The circulatory system was normal. Gastrointestinal examination (see present illness) showed that between attacks his appetite was good. The urinary examination was noncontributory.

Present Illness: Since the age of 10 to 11, the patient had been having attacks of cramplike pain in the abdomen, which had occurred several times a week to every few months. They had never been sufficiently severe for the patient to see a doctor. The intensity varied from mild to severe. They lasted from an hour to several days. During the attacks the patient vomited and had anorexia. The present illness started the day the patient was wounded. He had had mild cramps for two days before he was wounded but did not say anything about it. They became severe the third day after he was wounded, at the time when he was to be discharged from the hospital.

Physical Examination.—The physical examination gave negative results, as it had on admission, except for the acute condition within the abdomen, as described.

There was a soft blowing systolic murmur over the area of the pulmonary artery. Otherwise the heart was normal.

The patient was evacuated by air to the United Kingdom on the tenth day after the operation.

Follow-Up Report.—I had requested that the patient drop me a line as to his further progress during evacuation. I received a letter from the patient written a few days after he had arrived at a general hospital in the Zone of Communications. I then wrote to the chief of the surgical service of this hospital and received the following most interesting report from Lt. Col. Fred H. Miller. The patient had been admitted to this general hospital the day after he left the evacuation hospital. I quote herewith: "The patient was admitted to the General Hospital on March 3, 1945. His general condition appeared good. He was having six to seven liquid stools daily, with mild crampy abdominal pain. The wound was healing well. The patient was placed on a bland, low residue, high caloric diet. He was given bismuth subcarbonate, 30 grains (1.9 Gm.); tincture of opium, 10 minims (0.6 cc.) three times a day, one-half hour before meals; riboflavin, 10 mg. daily by mouth; thiamine hydrochloride, 10 mg.; nicotinic acid, 25 mg., and ascorbic acid, 200 mg. intravenously daily. On March 4, 1945 the bowel movements decreased to four liquid stools. At 10 p. m. the patient suddenly experienced a sharp pain just below the right knee in the calf, which progressed and radiated down to the toes. The foot was blanched, and no pulsation could be felt in the dorsalis pedis, posterior tibial or popliteal arteries on that side. Pulsation was also absent in the left dorsalis pedis and posterior tibial arteries, but the temperature and color of the left foot were normal. The patient was given ¼ grain (0.01 Gm.) of morphine immediately, with little relief. He was then given ½ grain (0.03 Gm.) of papaverine intravenously, and shortly thereafter the pain subsided completely but pulsation was still absent in both feet, and the right foot continued to show impairment in circulation.

On March 5, 1945 at 2 a. m. the patient was taken to the operating room, and a paravertebral block on the right side was done with 10 cc. of 1 per cent procaine hydrochloride. This caused some improvement in the peripheral circulation, manifested by warmth and dryness but no pulsation. Thereupon with the patient under anesthesia induced by 120 cc. of 0.5 per cent procaine hydrochloride solution by local infiltration, a 6 inch (15 cm.) incision was made over the right popliteal artery. Gastrocnemius bellies separated in the midline. The artery was exposed and showed no pulsation below the area of the knee joint. The artery was incised for a distance of 0.5 cm. There was no bleeding from the lower end but free bleeding from the upper end. Suction was applied, and about 1½ inches (4 cm.) of organized clot was removed. There was free bleeding from the lower end after this. Heparin, 5,000 units, was instilled in the artery, and the vessel was closed with three interrupted mattress sutures of 0000 silk. Closure was done with interrupted sutures in three layers. The artery pulsated below the suture on closure. The right foot was not blanched, and faint pulsation of the posterior tibial and dorsalis pedis artery could be felt at the end of the operation. The patient stood the procedure well. The patient returned from the operating room in good condition, with continuous intravenous administration of heparin. The color of the right foot remained good, and about six hours after the operation pulsation could be felt in the right posterior tibial artery but not in the left posterior tibial artery. The administration of heparin was continued, and papaverine, 1 grain (0.06 Gm.), was given every four hours.

On March 6, 1945 the general condition had remained good, the patient having about four large liquid bowel movements daily. Pulsation in the dorsalis pedis and posterior tibial arteries in both feet could be felt. The administration of

heparin was continued but the administration of papaverine was discontinued. The hemoglobin content was 82.5 per cent, hematocrit reading 38.6 per cent and protein level 6 Gm.

On March 7, the general condition of the patient was good. Bowel movement was the same. The circulation in both feet was excellent. The diet was changed to five feedings daily. Administration of bismuth was discontinued. One unit of blood plasma was given.

From March 7 to March 14 the condition of the patient continued to improve. The wounds were healing well. He continued to have about four large liquid bowel movements daily, putting out about 2,500 cc. of fluid by this route. His daily urinary output was about 500 to 600 cc. at first, but later this rose to 1,500 cc. per day. He showed no decrease in hemoglobin, chlorides or blood protein content.

With the wounds well healed, the general condition of the patient good and the circulation of the extremities good, it was decided that he could be safely evacuated to the Zone of the Interior by air as a litter patient; this was accomplished on March 26. On April 12 I received a letter from the patient, in which he stated that he was going on a three day pass and was going home for the week-end and then he was going to get a thirty day furlough. His return address was given as one of the named general hospitals in the states."

I then wrote to the chief of the surgical service of this hospital in the Zone of the Interior. I received the following reports from Lt. Col. John H. Gibbon Jr. The first report from Colonel Gibbon was dated June 5. I quote: "The patient arrived at this hospital in excellent condition, weighing 105 pounds (47.6 Kg.), on April 8. He has just returned from a thirty day furlough. While at home he avoided roughage and fatty and greasy foods but otherwise ate a normal diet. His bowels move two to three times daily. The stools are soft and frequently formed. He now weighs 113 pounds (51.3 Kg.); his best weight had been 140 pounds (63.5 Kg.), and he weighed 138 pounds (62.6 Kg.) when he was wounded. He shows no evidence of any vitamin deficiency. He looks normally nourished and appears strong and healthy. There is no circulatory deficiency in his right foot, and both pulses are palpable. Blood studies are normal except that he has slight hemoconcentration. On April 27 his hematocrit reading was 48.5 per cent. On April 13 there were 4,900,000 red blood cells and 4,000 white blood cells. The hemoglobin content was 15.9 Gm. (rechecked), the nonprotein nitrogen level 37 mg. and the sugar content 102 mg. per hundred cubic centimeters and the chloride level 99 milliequivalents per liter. His scar is firm, and there is no incisional hernia."

In further follow-up I wrote Colonel Gibbon once more and received the following report from him, written on August 13. "There is little additional information to give you concerning your patient. He received his discharge from the Army last week, after completion of some gastrointestinal studies. His motility test with carmine was forty-eight hours, which was considered normal. His weight was 115 pounds (52 Kg.). He has two soft stools daily that are mushy, but he has had no diarrhea. His blood count on June 26 showed 5,000,000 red cells, 6,200 white cells and 15.5 Gm. of hemoglobin per hundred cubic centimeters. He was tested for a number of days on several different diets. On all these diets there were large amounts of fat and starch in his stools. This was particularly pronounced on the high fat diet. It was also true on a medium carbohydrate and low fat diet. On a high protein, medium carbohydrate and low fat diet he lost weight. The diet on which he did best was a high carbohydrate, low fat and medium protein diet. All glucose tolerance tests were normal. Blood cholesterol, phosphorous, lipid and amylase levels were all within normal limits. Blood

chloride levels were also normal. The total serum protein content was 5.8 Gm. per hundred cubic centimeters, albumin 3.6 Gm. and globulin 2.2 Gm. The general condition of the patient was excellent, and I am sure that he will get along all right at home."

A letter received from the patient at the end of November 1945, from his home in the Middle West, states that he is well. His weight is now 120 pounds (54.4 kg.), and he has two to three bowel movements a day.

SUMMARY

A report is made of a case of an acute condition of the abdomen, requiring surgical intervention, complicating a battle-incurred wound by a shell fragment in the left arm and right thigh.

At operation it was found that the patient had a thrombosis of the superior mesenteric artery at a point just distal to the origin of the midcolic artery. This caused necrosis of all but the upper approximate 18 inches of the jejunum and all the large bowel up to the midtransverse colon. Resection of the necrotic bowel and a jejunocolostomy were performed.

The patient made a good surgical recovery and was evacuated by air on the eleventh postoperative day to a general hospital in the Zone of Communications.

At this hospital further arterial thrombosis developed, this time of the popliteal artery. An embolectomy on the right popliteal artery was successfully performed. Heparinization was employed here. It had not been available at the time of our intestinal resection at the forward echelon. The patient made a good recovery.

The patient was evacuated by air from the Zone of Communications to a named general hospital in the Zone of the Interior. Here he was studied, and it was found that he was absorbing sufficient nourishment from the remaining intestines to maintain good health.

The patient was discharged from the army and returned home. He was doing well nine months after the operation.

CONCLUSIONS

Removal of the entire small intestine except about 18 inches of the upper jejunum and removal of the large bowel to the midtransverse portion is apparently possible without serious digestive disturbances and inanition.

The patient did best on a high carbohydrate, low fat and medium protein diet.

Major Martin, of the named general hospital, will later report further nutritional studies of this case.

The etiology of the multiple major arterial thromboses in an apparently healthy young soldier of 19 years presents a fascinating problem.

Lieutenant Colonel Miller and Lieutenant Colonel Gibbon kept me informed of the progress and follow-up of the patient in this somewhat unusual case.

ZEPHIRAN CHLORIDE FOR THE PREOPERATIVE PREPARATION OF THE HANDS

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ZEPHIRAN chloride, a mixture of high molecular alkyldimethylbenzyl ammonium chlorides, is a cationic detergent and germicide. Domagk,[1] Dunn,[2] Baker and colleagues,[3] White and colleagues,[4] Walter,[5] Schumacker and Bethea,[6] Hauser and Cutter [7] and others have appraised its value as a germicide and pointed out its usefulness in the field of surgery.[8] It is the purpose of this report to present the results obtained while its value was being investigated in use as a mechanical and chemical cleansing agent for the preoperative preparation of the hands, to compare its worth as a detergent when used for this purpose with that of medicinal soft soap and to compare its merits as a bactericide with those of 70 per cent alcohol when employed as a chemical cleansing agent.

Domagk [1] first pointed out some of the physical properties of zephiran chloride. It is a colorless, almost odorless liquid, which foams on shaking and is slightly alkaline to litmus. It does not precipitate with alkalis and remains clear when tap water is added, and there is

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8. No attempt was made to review the literature completely.

no precipitate or loss of bactericidal power with the addition of acids. It is compatible with most substances with which it is likely to come in contact in the operating room.[7] It is stable over a wide range of temperatures; freezing, storage at above 50 C. for eighteen days and storage at room temperature for over eight months caused no apparent loss in germicidal efficacy.[2a,b] It has a detergent and emollient action and is not irritating to the skin. The hands when wet with zephiran chloride solution become soft and smooth and remain so for several hours after the skin has become dry. Soap exerts an inactivating influence on zephiran chloride.

Miller and his associates[9] have demonstrated that zephiran chloride deposits an invisible film on the hands. The film retains bacteria beneath it and is said to be extremely resistant to ordinary mechanical trauma. This may in part be responsible for the decrease in the number of bacteria that can be removed from the cutaneous surface after zephiran chloride is used. Zephiran chloride also kills bacteria, and Valko and Dubois[10] have shown that the "killing" action of the surface-active cations on bacteria can be reversed under certain conditions by detoxication with a high molecular anion. They stated that the initial process in the action of surface-active cations can be satisfactorily described as a reversible adsorption by the bacteria, which function as cationic exchangers. Little is known about the course of events which follows this primary process and finally leads to the death of the bacteria.

PLAN OF EXPERIMENTAL STUDIES

Since zephiran chloride is a detergent and also a germicide, it can be employed for both mechanical and chemical cleansing of the skin. While these investigations were being carried out, it was desirable (1) to establish its value as a detergent for scrubbing the hands and arms and to compare its worth when used for this purpose with that of medicinal soft soap and (2) to determine its value in use as a chemical cleansing agent and to compare its worth with that of 70 per cent alcohol. It was also desirable to establish the necessity for mechanical cleansing of the hands and arms between clean operations when zephiran chloride is employed as a chemical cleansing agent. Because of the fact that soap exerts an inactivating influence on zephiran chloride, it was advisable to determine whether an aqueous solution of zephiran chloride can be used in the operating room as a chemical cleansing agent after one has scrubbed with soap and water.

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9. Miller, B. F.; Abrams, R.; Huber, D. A., and Klein, M.: Formation of Invisible, Non-Perceptible Films on Hands by Cationic Soaps, Proc. Soc. Exper. Biol. & Med. **54**:174-176, 1943.

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GENERAL PROCEDURE

Mechanical cleansing of the hands and arms was performed by scrubbing for eight minutes, a 1:500 aqueous solution of zephiran chloride and medicinal soft soap being used for comparison as detergents. Two brushes were used, one being discarded after the hands were scrubbed for three minutes. The nails were cleaned with an orangewood stick after the first brush was discarded. Tap water was used in combination with the detergents in all these experiments. After mechanical cleansing was performed, the hands and arms were washed with a washcloth for three minutes in a basin containing ½ gallon (1.9 liters) of the solution used for chemical cleansing. Immediately after preparation of the hands, a culture was taken of the solution after the hands up to the wrists had been washed for one minute in a basin containing 500 cc. of sterile isotonic solution of sodium chloride. Five cubic centimeters of the isotonic solution of sodium chloride was removed from the basin with a sterile pipet and placed in a blood-dextrose agar pour plate and incubated for forty-eight hours. The colonies on the plate after forty-eight hours of incubation were counted, and the number of bacteria in the 500 cc. of isotonic solution of sodium chloride was estimated.

After the first culture was taken, sterile gloves were put on the hands, the dry technic being used. A rubber band was placed around the arms at the tops of the gloves to prevent, so far as possible, contaminated perspiration from getting into the gloves. Gowns were not worn. After a period of one hour had elapsed, the gloves were removed and another culture was taken as previously described. During this one hour period the subjects who assisted in these experiments continued their usual hospital duties, and no attempt was made to keep the outsides of the gloves sterile.

After the second culture was taken the hands were washed with a washcloth for three minutes in the solution used for chemical cleansing, and a third culture was taken in the manner as described in the first paragraph. Chemical cleansing was performed after gloves had been worn for one hour in an effort to determine the necessity for mechanical cleansing between clean operations.

When cultures were taken by this method, a small amount of the chemical cleansing agent was washed from the hands into the isotonic solution of sodium chloride and subsequently transferred to the culture plate. Although these substances were diluted considerably, it was necessary to determine whether their presence in the culture mediums would cause sufficient bacteriostasis to alter the results. Five experiments were performed in which the gloved hands were immersed in a 1:1,000 aqueous solution of zephiran chloride and in a 70 per cent solution of alcohol. These substances were washed off the hands into 500 cc. of sterile isotonic solution of sodium chloride. Five cubic centimeters of the isotonic solution of sodium chloride was placed in tubes containing 10 cc. of dextrose agar and 2 cc. of blood which had been previously inoculated with 0.1 cc. of an emulsion of Staphylococcus aureus bacteria. There was no significant difference in the number of colonies of bacteria growing on the plates after forty-eight hours' incubation when compared with cultures that were inoculated as controls. The alcohol and zephiran chloride washed from the hands were diluted by the isotonic solution of sodium chloride and blood agar to such an extent that bacteriostasis sufficient to alter the results did not occur.

Many factors influence the number of bacteria remaining on the surface of the hands after mechanical and chemical cleansing. It was thought, however, that by the performance of the same experiment fifteen times the results would be satisfactory for comparison. It is not felt that the absence of growth of

organisms in cultures taken in this manner indicates that the hands are sterile. It appears that absolute sterility of the skin of the hands and forearms is impossible to attain.[11]

These experiments were performed by subjects in groups of five. Subjects were members of the resident house staff, nurses assigned to the operating room and medical students who were familiar with the art of scrubbing. The hands were not washed and the nails were not cleaned before the experiments were begun. No subject performed the experiment oftener than once each day. The temperature could not be kept constant. Every precaution was taken to prevent the isotonic solution of sodium chloride in the basins from becoming contaminated with air-borne bacteria. The basins were covered with sterile towels, and the experiments were performed in the operating room under bactericidal irradiation to further minimize contamination from the air.

TABLE 1.—*Bactericidal Effect of Soap and Water Plus Alcohol*

Results of Cultures after Scrubbing for Eight Minutes and Washing in 70 per Cent Alcohol for Three Minutes.

	Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing in 70 per Cent Alcohol 3 Minutes, Number of Bacteria
1	2,500	800	2,700
2	1,900	2,200	200
3	14,400	43,200	4,800
4	208,000	171,600	25,600
5	4,800	24,200	1,600
6	9,000	20,000	6,600
7	500	800	6,900
8	83,200	49,600	64,000
9	1,900	9,100	2,700
10	1,600	8,800	2,200
11	3,200	2,500	9,200
12	300	100	800
13	900	100	700
14	1,100	1,900	Negative
15	100	Negative	400

EXPERIMENTS AND RESULTS

In the first experiment the hands and arms were prepared by scrubbing for eight minutes with medicinal soft soap and tap water and by washing for three minutes in 70 per cent alcohol. The results are listed in table 1. All cultures taken immediately after preparation of the hands were positive for bacterial growth. Only two negative cultures were obtained in the entire series. In eight instances there was an increase in the number of bacteria removed from the surface of the hands after gloves had been worn for one hour. Only one culture, taken after chemical cleansing had been performed for the second time, was negative for bacterial growth.

To establish the value of zephiran chloride as a chemical cleansing agent for the hands and arms, the following experiments were performed. The hands and arms were prepared by scrubbing with

11. Lovell, D. L.: Skin Bacteria: Their Location with Reference to Skin Sterilization, Surg., Gynec. & Obst. **80**:174-177, 1945.

medicinal soft soap and water for eight minutes and by washing in solutions of 1 : 1,000 zephiran chloride for three minutes. The solutions employed for chemical cleansing were zephiran chloride tincture (containing 50 per cent alcohol, U. S. P.), zephiran chloride tincture (containing 50 per cent alcohol, U. S. P., and 10 per cent acetone) and

TABLE 2.—*Bactericidal Effect of Soap and Water Plus Zephiran Chloride Tincture Without Acetone*

Results of Cultures after Scrubbing for Eight Minutes and Washing in 1:1,000 Zephiran Chloride Tincture Without Acetone for Three Minutes.

	Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing in Zephiran Chloride for 3 Minutes, Number of Bacteria
1	1,000	33,600	300
2	9,500	80,000	400
3	300	17,600	1,300
4	300	24,000	400
5	48,000	172,000	56,000
6	3,300	26,000	15,100
7	7,100	129,600	1,700
8	300	1,400	100
9	4,100	4,700	700
10	Negative	35,200	16,500
11	700	252,800	100
12	100	25,600	Negative
13	400	1,100	100
14	100	3,300	500
15	6,400	49,600	1,100

TABLE 3.—*Bactericidal Effect of Soap and Water Plus Zephiran Chloride Tincture Containing Acetone*

Results of Cultures after Scrubbing for Eight Minutes and Washing in 1:1,000 Zephiran Chloride Tincture Containing 10 per Cent Acetone for Three Minutes.

	Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing in Zephiran Chloride for 3 Minutes, Number of Bacteria
1	200	1,800	100
2	200	1,600	180
3	400	25,600	500
4	200	20,800	Negative
5	500	300	Negative
6	200	10,200	200
7	57,600	Uncountable	7,600
8	Negative	5,600	800
9	4,100	28,800	Negative
10	6,300	1,700	4,300
11	1,100	5,800	4,700
12	7,000	22,400	2,400
13	4,200	11,800	6,600
14	1,500	33,600	1,000
15	12,200	9,600	3,400

aqueous solution of zephiran chloride. The results are listed in tables 2, 3 and 4 respectively. The best results were obtained when the aqueous solution was employed. Thirteen of the cultures, taken immediately after preparation of the hands, were negative for bacterial growth. Eight subjects had negative cultures after wearing gloves for one hour. Twelve cultures, taken after chemical cleansing had been

repeated, were negative for bacterial growth. All three cultures taken of 6 of the subjects were negative.

To determine the value of zephiran chloride as a detergent for use in mechanical cleansing, the hands and arms were scrubbed for eight

TABLE 4.—*Bactericidal Effect of Soap and Water Plus Aqueous Solution of Zephiran Chloride*

Results of Cultures after Scrubbing for Eight Minutes and Washing in 1:1,000 Aqueous Solution of Zephiran Chloride for Three Minutes.

	Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing in Zephiran Chloride for 3 Minutes, Number of Bacteria
1	Negative	Negative	Negative
2	Negative	400	Negative
3	Negative	Negative	Negative
4	Negative	Negative	100
5	Negative	Negative	200
6	Negative	Negative	Negative
7	Negative	100	Negative
8	Negative	1,100	Negative
9	Negative	Negative	Negative
10	Negative	Negative	Negative
11	Negative	20,800	1,200
12	600	256,000	Negative
13	100	1,100	Negative
14	Negative	200	Negative
15	Negative	Negative	Negative

TABLE 5.—*Bactericidal Effect of Scrubbing and Washing with Aqueous Solutions of Zephiran Chloride*

Results of Cultures after Scrubbing with 1:500 Aqueous Solution of Zephiran Chloride for Eight Minutes and Washing with 1:1,000 Aqueous Solution of Zephiran Chloride for Three Minutes.

	Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing with 1:1,000 Solution of Zephiran Chloride for 3 Minutes, Number of Bacteria
1	Negative	3,600	1,200
2	200	4,800	2,000
3	2,200	4,000	500
4	6,800	41,600	8,900
5	200	100	1,000
6	6,400	3,000	2,400
7	4,800	5,000	400
8	5,600	2,000	2,100
9	1,100	200	600
10	1,800	800	800
11	Negative	200	500
12	Negative	3,400	700
13	Negative	4,600	Negative
14	Negative	100	1,200
15	Negative	3,900	200

minutes with a 1 : 500 aqueous solution of zephiran chloride and then washed in a 1 : 1,000 aqueous solution of zephiran chloride for three minutes. The results are listed in table 5. They were not so satisfactory as those obtained when medicinal soft soap was used as a detergent.

Inasmuch as zephiran chloride is a cationic detergent and soap is an anionic detergent, soap should not be mixed with zephiran chloride. When the cutaneous surface is scrubbed with soap and water, it is difficult to remove all the soap. If the hands and arms are washed in a basin containing zephiran chloride after being scrubbed with soap and water, it is difficult to prevent the transfer of a small amount of the soap to the zephiran solution. To determine the practical importance of this, a basin containing two gallons (7.5 liters) of a 1 : 1,000 aqueous solution of zephiran chloride was placed in the operating room for use as a chemical cleansing agent following mechanical cleansing with soap and water. The solution was not changed during the day. The number of persons that used the solution for chemical cleansing was recorded. At the end of the day 5 subjects used this solution as a

TABLE 6.—*Bactericidal Effect of Soap and Water Plus Aqueous Solution of Zephiran Chloride*

Results Obtained after Scrubbing for Eight Minutes and Washing in 1:1,000 Aqueous Solution of Zephiran Chloride for Three Minutes, the Zephiran Being Previously Used All Day in the Operating Room Before Being Employed for These Experiments. Two Gallons (7.5 Liters) of the Zephiran Solution Was Placed in the Wash Basin at the Beginning of the Day.

		Culture After Preparation of the Hands, Number of Bacteria	After Gloves Were Worn for 1 Hour, Number of Bacteria	After Washing in Zephiran Chloride for 3 Minutes, Number of Bacteria
Zephiran chloride previously used by 29 persons	1	500	400	500
	2	300	9,400	300
	3	5,400	80,000	3,500
	4	3,200	22,400	3,600
	5	200	3,700	500
Zephiran chloride previously used by 42 persons	1	1,100	168,400	1,100
	2	1,300	38,400	1,200
	3	20,800	320,000	7,600
	4	2,300	35,200	800
	5	700	3,200	1,000

chemical cleansing agent after scrubbing with soap and water for eight minutes. Cultures were taken immediately after preparation of the hands, after gloves had been worn for one hour and after chemical cleansing had been repeated following removal of the gloves. The results are listed in table 6. In both experiments the zephiran chloride was inactivated to such an extent that its bactericidal power was reduced. Although all the cultures were positive for bacterial growth, the results were as good as those obtained when fresh 70 per cent alcohol was employed.

COMMENT AND CONCLUSIONS

Zephiran chloride is a good chemical cleansing agent for use in the preoperative preparation of the hands and arms. In these experiments a 1 : 1,000 aqueous solution of zephiran chloride and 1 : 1,000 zephiran chloride tincture (containing 50 per cent alcohol, U. S. P., and 10 per cent acetone) proved to be better chemical cleansing agents

than 70 per cent alcohol. The results obtained with the aqeous solution were better than those achieved with the use of zephiran chloride tincture. The reason for this may be twofold: First, when the hands are washed in these solutions the film on the cutaneous surface appears to be more perceptible when the aqueous solution is employed, and, second, since the zephiran chloride tincture has greater penetrating power than the aqueous solution, contaminated sebaceous material may have been washed out of the pilonidal follicles onto the cutaneous surface and the bacteria remained viable because of the inability of the zephiran chloride to penetrate the sebaceous material and cause their death.

Soap proved to be a better detergent for mechanical cleansing of the hands and arms than aqueous solution of zephiran chloride. The best results were obtained when soap was used as a detergent for mechanical cleansing and a 1:1,000 aqueous solution of zephiran chloride was employed as the chemical cleansing agent. When these two substances are used for the preoperative preparation of the hands and arms, great care must be taken to remove the soap from the skin before chemical cleansing is performed. This is necessary because soap exerts an inactivating influence on zephiran. Most of the soap can be removed from the hands and arms by scrubbing with a clean brush in running tap water for one minute. When chemical cleansing is performed by washing of the hands and arms in a basin containing zephiran chloride this solution should be changed frequently. This problem may also be solved by applying the zephiran chloride to the hands and arms with a dispenser. When zephiran chloride is used as a chemical cleansing agent for the preoperative preparation of the hands, it is not necessary to scrub with soap and water between clean operations; flushing the hands and arms in running tap water to remove the powder and perspiration and then washing in a 1:1,000 solution of aqueous zephiran chloride for three minutes will be satisfactory. .

Members of the operating room staff cooperated in these experiments.

REPAIR OF DEFECTS OF THE SKULL

With Special Reference to the Periorbital Structures and Frontal Sinus

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CONSIDERABLE experimental and clinical evidence has accumulated to establish the biologically inert character of tantalum as an alloplastic material for the repair of defects of the skull. Pudenz [1] demonstrated the tolerance of brain tissue for tantalum clips and later showed the metal to be noncorrosive and nontoxic when used in the skull.[2] This has been substantiated by the work of others, notably, Carney,[3] Burke [4] and Fulcher.[5] In the past few years, several extensive reports on the use of this material in large series of cases have been published and the general principles and methods have been established. Woodhall and Spurling [6] and Robertson [7] have demonstrated its applicability in the repair of defects caused by war wounds, while Echols and Colcough [8] and Gardner [9] have employed it in the repair of defects such as are seen in civilian practice. In the latter instance, tantalum sheet metal has been extremely satisfactory in repair of the defects following operative treatment of osteomyelitis of the frontal bone and involvement of the calvarium by tumor and in other conditions in which the diseased bone must be removed.

The present consideration is of a specialized use of tantalum, namely, in the reconstruction of defects involving the frontal region, particu-

1. Pudenz, R. H.: The Use of Tantalum Clips for Hemostasis in Neurosurgery, Surgery **12**:791-797 (Nov.) 1942.

2. Pudenz, R. H.: The Repair of Cranial Defects with Tantalum, J. A. M. A. **121**:478-481 (Feb. 13) 1943.

3. Carney, H. M.: An Experimental Study with Tantalum, Proc. Soc. Exper. Biol. & Med. **51**:147-148 (Oct.) 1942.

4. Burke, G. L.: The Corrosion of Metals in Tissues: An Introduction to Tantalum, Canad. M. A. J. **43**:125-128 (Aug.) 1940.

5. Fulcher, O. H.: Tantalum as a Metallic Implant to Repair Cranial Defects: A Preliminary Report, J. A. M. A. **121**:931-933 (March 20) 1943.

6. Woodhall, B., and Spurling, R. G.: Tantalum Cranioplasty for War Wounds of the Skull, Ann. Surg. **121**:649-671 (May) 1945.

7. Robertson, R. C. L.: Repair of Cranial Defects with Tantalum, J. Neurosurg. **1**:227-236 (July) 1944.

8. Echols, D. H., and Colcough, J. A.: Cranioplasty with Tantalum Plate, Surgery **17**:304-314 (Feb.) 1945.

9. Gardner, W. J.: Closure of Defects of the Skull with Tantalum, Surg., Gynec. & Obst. **80**:303-312 (March) 1945.

larly those in which the outer or both walls of the frontal sinus have been destroyed and in which the supraorbital ridges and orbital margin are included in the defect.

Small defects involving the supraorbital ridge or the frontotemporal angle of the forehead give rise to deformities which are out of proportion to the amount of bone loss. Surgical procedures on the frontal sinuses for the treatment of suppurative sinusitis frequently leave defects, the repair of which by autogenous plastic procedures is complicated and difficult. The radical removal of bone, which is necessary at times in the treatment of acute osteomyelitis of the frontal region, is particularly disfiguring. While it may be possible to retain much of the supraciliary arch in elective surgical procedures, this is not always so in the extensive comminuted fractures of the frontal region which result from vehicular accidents. The presence of a depressed area in the frontal region, where normally a convex surface exists, results in a distortion of the facial characteristics of a person. The contour of the frontal region is peculiar to each person, and care must be taken not only to preserve the vertical and lateral curvature but also to maintain the angle which exists between the frontal and temporal regions. This angle is formed in part by the lateral orbital wall, and a defect in this region results in a flattened appearance of the side of the head and undue prominence of the eye. This region is particularly important when the eye has been enucleated. The loss of the orbital fat pad (common in war wounds) and the tendency for the intraorbital tissues to retract necessitate reconstruction of the shelving portion of the supraorbital ridge as well as of the lateral orbital rim.

Prior to any detailed consideration of the various types of defects, the importance of countersinking the tantalum plate until it is level with the surface of the bone must be emphasized. Not only does this insure the best cosmetic result, but, it is my belief, repeated accumulation of fluid between the plate and the scalp is not infrequently caused by irritation from a plate which is insecurely anchored. In 1 known instance, fluid repeatedly accumulated after aspiration for several months in the occipital region where a tantalum plate had been loosely sutured to the pericranium. When the plate was removed there was no evidence of infection nor was the plate in any way adherent to the surrounding tissues. When small, well placed tantalum wedges driven into the diploic space are used, the position and immobility of the plate are insured. This is important in the frontal region, where frequently only the superior edge of the plate can be fastened.

It should also be emphasized at this time that the tantalum plate may be fashioned at the operating table and placed over a defect at the time of primary operation. While it may not be desirable to do this when there has been active acute infection, it is certainly feasible

and often desirable in the average traumatic wound. Tantalum itself causes no severe reaction in the presence of infection nor, as a foreign body, does it prevent healing in the presence of infection provided adequate drainage of the infected area is established and maintained before the formation of multiloculated pockets and walled-off areas under the plate. Should the latter be allowed to form, removal of the plate eventually may become necessary. The radical removal of infected bone in the treatment of sinusitis may be followed by tantalum cranioplasty to restore the cosmetic appearance,[10] and if all the diseased bone is removed and adequate drainage established through the nose the plate may be put in shortly after the primary operation. Whenever tantalum is used at the time of primary operation, the same care should be taken in fashioning of the plate and preservation of the contour of the frontal region as in the repair of any cosmetic defect.

I. DEFECTS INVOLVING THE LATERAL ORBITAL RIM

In this group are the defects in which the loss of bone often includes the zygomatic process of the frontal bone, either completely or partially. In the severe wounds which involve this lateral portion of the supraciliary arch, the upper portion of the frontal process of the zygomatic bone may be included in the defect. In few instances is the defect in the bone limited only to these structures, and there is almost always some loss of bone in the adjacent areas, including the frontal or temporal regions or both. As has been stated previously, the resulting deformity not only causes undue prominence of the eye but gives a flattened appearance of the side of the head. The deformity is frequently accentuated by loss of temporal muscle as a result of either tissue destruction from the injury itself or loss from necessary débridement of the wound. It is possible to a limited degree to compensate for soft tissue deformity by careful contouring of the tantalum plate, but as a general rule it is best to attempt to reconstruct only the pattern of the bone and to reserve soft tissue deformities for correction by other plastic procedures.

When the defect is small and underlies a relatively normal temporal muscle, there is no need to cover it with a plate. However, when the defect is large and particularly when the overlying muscle is thin and the area sunken, the plate for the orbital defect should be formed with an extension to underlie the temporal muscle. It must be remembered that the temporal fossa is deep and is concave but when normally filled with muscle tends to have a moderately flat contour as compared with the convex surface of the frontal bone. In the final preparation of the plate at the operating table, this fronto-

10. Canfield, N., and others: Tantalum Implants for Skull Defects, Proc. Roy. Soc. Med. **38**:293-298 (April) 1945.

temporal angle must be taken into account, particularly after the muscle has been stripped from its attachments. The anterior attachment of the temporal muscle at the superior temporal line, actually an upward and slightly posterior projection of the zygomatic process of the frontal bone, is the critical point in the reconstruction of this region. It has been the practice, whenever possible, to form the edge of the tantalum plate about the root of the zygomatic process to insure a proper contour. The following 2 cases are illustrations of defects such as have been discussed.

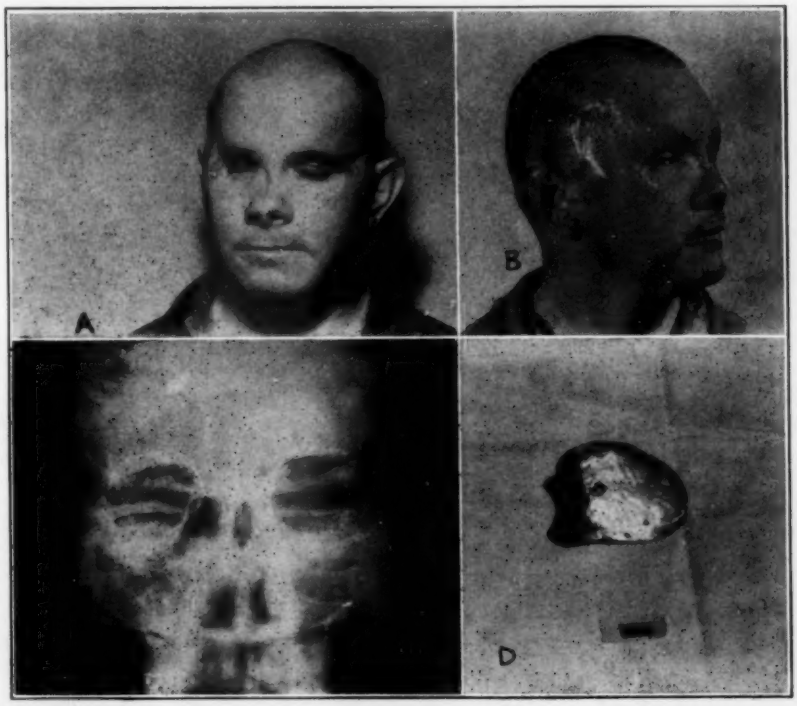

Fig. 1 (case 1).—*A*, preoperative photograph to show the defect in the lateral orbital wall and the temporal region. *B*, postoperative photograph to show the reconstruction of the lateral orbital rim. *C*, preoperative roentgenogram showing the absence of the lateral portion of the supraorbital ridge and lateral orbital rim. Roentgenogram was reversed in photography. *D*, tantalum plate. Note the contouring of the edge to form a shelf.

Case 1.—A soldier was wounded when an enemy mine exploded on April 19, 1945. He received multiple wounds of the face, nose and head, with a penetrating wound of the right frontotemporal region, which destroyed the right eye. Traumatic cataract, with adhesions of the iris, developed in the left eye, and the patient was left with minimal vision. In preparation for further plastic procedures, the soldier was admitted to the hospital for reconstruction of the defect of the skull.

There was loss of bone in the right temporal region and at the lateral aspect of the orbital rim. The temporal muscle was extremely thin, and the area of the

defect was sunken (fig. 1 *A*). The extreme lateral portion of the supraciliary arch was missing, along with the corresponding portion of the orbital margin, and the zygomatic process was absent (fig. 1 *C*). The defect measured 5 cm. vertically and about the same horizontally.

A plate was fashioned which would adequately cover the defect under the temporal muscle as well as restore the missing portion of the orbital rim. Because adequate exposure could not be obtained through the irregular scar of the old incision, a small scalp flap was reflected in the temporal region, with the base placed anteriorly. It should be noted that a simple flat plate was not used but that a shelving portion which could be contoured about the remnant of the zygomatic process was utilized.

In this instance, the defect in the temporal region was such that the anterior edge of the plate formed the margin of the superior temporal line and the normal frontotemporal angle was restored (fig. 1 *B*).

CASE 2.—A soldier received a gutter type bullet wound in the right frontotemporal region on April 14, 1945, which resulted in extensive loss of bone. The defect involved a large portion of the squamous temporal region, the frontal bone, including the lateral two thirds of the supraciliary arch and zygomatic process, and the right frontal sinus (fig. 2 *C*). There was considerable depression of the temporal region, and the right globe appeared prominent, owing to destruction of the frontotemporal junction (fig. 2 *A*).

A large plate was fashioned which covered all portions of the defect. It was necessary to form a sharp angle between the frontal and temporal portions of the plate, and the exact amount of depression of the subtemporal portion of the plate was adjusted at the operating table (fig. 2 *D*). In this instance the posterior portion of the plate was not fastened with wedges, and it was necessary to do this at a second procedure because of excessive prominence of the temporal region due to "springing" of the free portion of the plate. The final result was one of restoration of both the frontal and the temporal contour, with the formation of a normal-appearing supraorbital ridge (fig. 2 *B*).

It was possible to obtain adequate exposure of the entire region through the original operative incision. This is usually the case, but occasionally it may be necessary to use another approach. When the approach is one of election, a concealed incision should be used when possible. This case illustrates the necessity of fastening the plate, particularly at points where there may be a tendency for the plate to "spring."

II. DEFECTS INVOLVING THE SUPERIOR ORBITAL RIM, THE ANTERIOR ORBITAL PLATE AND THE FRONTAL SINUS

Whether the defect is confined to this anterior portion of the frontal bone or whether there is additional loss to include the frontal eminence, the problem of repair is essentially the same, namely, the restoration of a normally positioned and normally curved supraciliary arch. A second and equally important function of any plastic procedure in this region is the restoration of the anterior portion of the orbital plate when this is absent.

Injury to this region is often associated with damage to the orbital contents, frequently with destruction of the eye itself, and a common sequence is partial loss or shrinkage of the intraorbital contents. This eventually results in retraction of the overlying soft tissues, particularly of the upper eyelid. While this soft tissue deformity cannot be completely restored by the use of tantalum, the reconstruction of the anterior portion of the orbital roof by means of a shelving border to

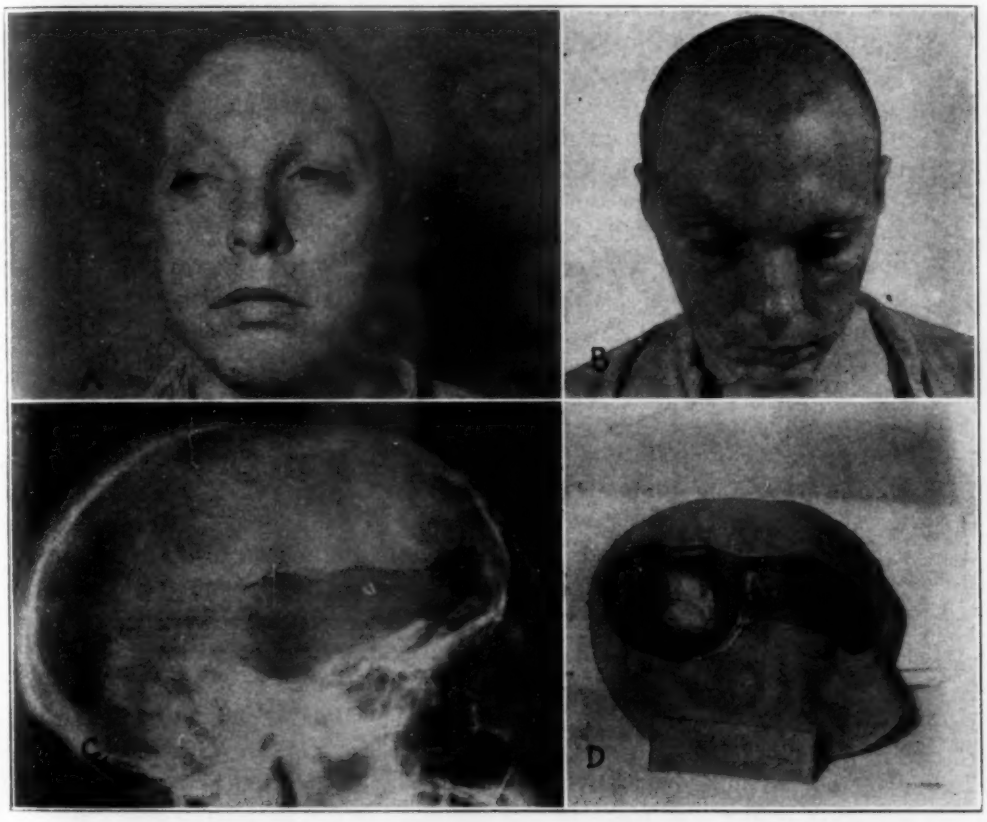

Fig. 2 (case 2).—*A*, preoperative photograph to show the deformity caused by the absence of the lateral half of the supraorbital ridge. Note the prominence of the eye. *B*, postoperative photograph showing the reconstruction of the supraorbital ridge and frontotemporal angle. *C*, lateral roentgenogram showing the extent of the defect, which involved both frontal and temporal regions. *D*, tantalum plate. Note the angle at the frontotemporal region and the depressed area to underlie the temporal muscle.

the tantalum plate can do much to lessen the deformity. In the formation of such a plate, there is a tendency to underestimate the degree of curvature, particularly since the curves must be present in two separate planes. The curve of the plate should be slightly overcom-

pensated to allow for the slight decrease in thickness, through scarring, of the overlying soft tissues.

The plate may be placed too high, and one must rely on available landmarks to determine the correct position. The newly formed ridge should conform as nearly as possible to that of the opposite side. When both ridges are absent or when the opposite one cannot be used as a landmark, the presence of a small amount of retained arch at either end is of considerable assistance. There is frequently considerable scar contracture of the upper eyelid, with the eyebrows being displaced downward and even into what remains of the upper lid. This scarring may be such as to prevent the placing of the plate low enough to correspond with the opposite side. After cranioplasty and the restoration of the normal convex surface, the displaced eyebrow may return to the normal position but often with shortening of the upper lid. For this reason, plastic procedures on the lids should not be undertaken until the bony contour has been restored. The substitution of the soft tissues of the supraciliary region for the upper lid may often be recognized by the presence of a portion of the eyebrow on what appears to be lid itself.

In the restoration of the ridge, it is not sufficient to obtain the proper position and lateral curve of the opposite side. There is considerable difference among persons, and in those with large frontal sinuses and prominent brows the most difficulty may be had in obtaining corresponding prominence of the ridge. The orbital margin is actually the most anterior extent of the orbital plate, and the positioning of the plate evenly with it will result in loss of the usual frontal prominence of the brow. It is not necessary to countersink that portion of the plate which is contiguous with the remnants of the supraorbital ridge, but when sufficient of the latter structure is present the lower edge of the plate may be fastened with a small tantalum wedge.

In several cases an open frontal sinus has been exposed when the primary injury did not result in entire destruction of both walls. It has been the practice to make certain that no mucous membrane remains lining the cavity but to do nothing beyond that. There have been no infections which could be ascribed to exposure of the open sinus. The following cases illustrate the type and extent of the defects which have been discussed. While these cases are all cases of war injuries, they closely resemble those which are seen after accidents or surgical procedures in this region.

CASE 3.—A soldier received a compound, comminuted fracture of the left frontal region when he was struck by high explosive shell fragments on Feb. 6, 1945. The injury destroyed the left eye and shattered both walls of the frontal sinus and a portion of the roof of the orbit. At the time of admission for cranioplasty, examination disclosed the entire supraorbital ridge and the anterior portion of the orbital plate to be absent (fig. 3*A*). Except for a small bony prominence

situated laterally, there was nothing to indicate the normal position of the supraciliary arch. The medial half of the eyebrow was nearly in its normal position, but the lateral half was pulled down over the badly scarred and contracted tissues which formed the upper eyelid. The soft tissues in the region were all involved in the scar, adding to the deformity caused by the loss of bone.

A plate was fashioned, with a considerable shelving lower border, to correct the loss of bone from the orbital margin and anterior orbital roof (fig. 3 *D*). Because of the excessive prominence laterally, due to anterior displacement of

Fig. 3 (case 3).—*A*, preoperative photograph showing the absence of the left supraorbital ridge. Note the scar and retraction of the upper eyelid. *B*, postoperative photograph showing the reconstruction of the ridge. *C*, preoperative roentgenogram showing the complete absence of the supraorbital ridge and the anterior orbital plate. *D*, postoperative roentgenogram showing the position of the tantalum plate.

one of the bone fragments, it was impossible to obtain an even contour to the ridge. Accordingly, a ridge was formed to correspond to the normal position rather than to the displaced lateral angle. The badly scarred and shortened upper lid also interfered with the placing of the medial border of the plate as low as would have been desired. The superior margin of the defect was shelved to allow

the plate to lie evenly with the surface of the skull, and the plate was held in position by several wedges driven into the diploic space along the upper border.

Postoperatively, there was considerable improvement in the position of the displaced lateral half of the eyebrow. While a perfect supraorbital ridge was not obtained, there was much improvement over the preoperative appearance and there was formed a structure on which further plastic procedures could be carried out on the soft tissues (fig. 3*B*). During the operation, the anterior portion of what remained of the right frontal sinus was exposed. The sinus was free of mucous membrane, and nothing further was done to it.

This case illustrates the difficulties which may be encountered when there is excessive scarring of the soft tissues and displacement of the bone structures surrounding the defect. The necessity for an adequate exposure and the severity of the local scar precluded use of the original incision, and a frontal scalp flap, with most of the incision concealed behind the hair line, was used.

CASE 4.—A soldier was injured in a motorcycle accident in Germany on June 28, 1945, in which he sustained a compound, comminuted and depressed fracture of the left frontal region, with penetration of the dura and brain. At the time of primary operation, a left frontal scalp flap was reflected and the depressed fragments of bone removed. The fracture included both walls of the frontal sinus and a portion of the anterior aspect of the orbital plate.

At the time of admission there was a pulsating, oval defect in the left frontal region, which measured 6.5 by 4.5 cm. The supraorbital ridge was absent except for its lowermost edge and a small remnant of bone which could be palpated above the outer canthus of the eye (fig. 4*A*).

The operative area was approached through the scar of the previous incision. There was some thinning of the bone edges, and the plate was allowed to overlap sufficiently to cover the thinned area. A plate had been fashioned with a shelved lower border to compensate for the defect in the orbital plate, and at the time of operation this border was adjusted to correspond with the plane of the remaining bone forming the orbital roof. Postoperatively, there was excellent restoration of the contour of the brow and forehead (fig. 4*B*).

In addition to the destruction of the supraorbital ridge there was a considerable defect involving the region of the frontal eminence, and this necessitated careful contouring of the upper portion of the plate. In the process of exposing the defect, the scalp must be dissected from the underlying dura. Usually a fairly distinct cleavage plane may be found between the two structures, but if the defect is of long standing or if there has been intercurrent infection scar tissue may make the dissection difficult. If the dura is inadvertently opened, it should be closed with several interrupted fine silk sutures.

In extensive bifrontal injuries there is often destruction of the glabella and frequently of the upper portion of the nasal bridge as well. In such instances a plate can be formed which includes the upper portion of the nasal bridge. If there is only a small defect in the nasal bridge, a coronal incision may be used and the operative site exposed by reflection of the scalp forward. However, if the nasal defect is

large or if the soft tissues are severely scarred and adherent in this region, it may be difficult to expose the upper edge of the nasal bone through such an incision. If the nasal defect is to be repaired, it may be best in some cases to approach the operative site through an incision which passes through the region of both eyebrows and across the nasal bridge. Great care must be exercised not to enter the nasal cavity in the dissection, and the edge of the tantalum plate must fit perfectly with the upper edge of the nasal bone or an unsightly elevation will result.

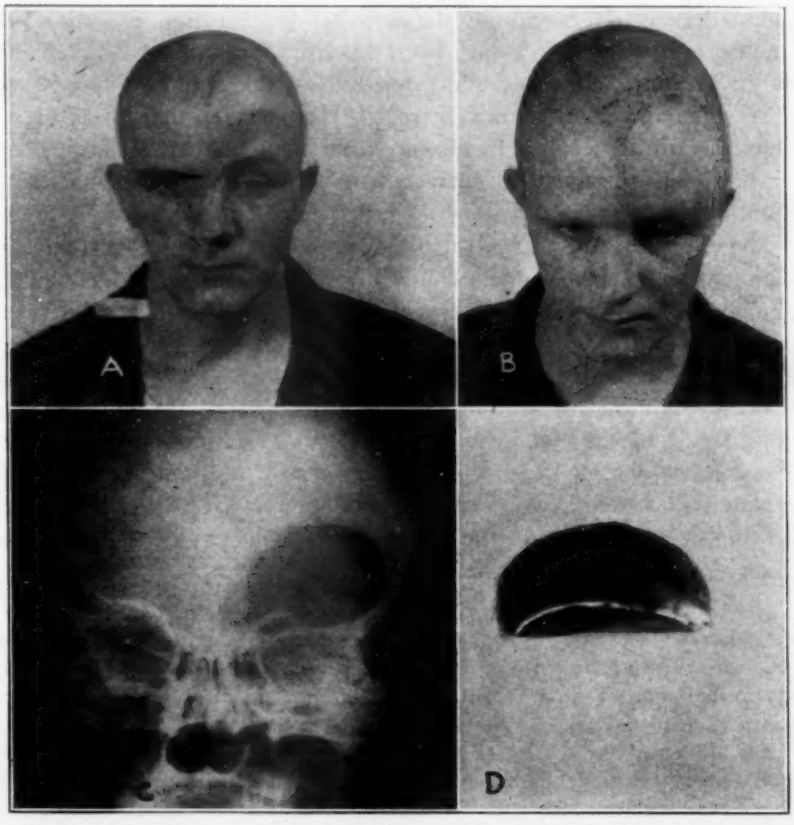

Fig. 4 (case 4).—*A*, preoperative photograph showing defect involving the frontal region and part of the supraorbital ridge. *B*, postoperative photograph. Note the presence of the formed ridge and normal frontal contour. *C*, preoperative roentgenogram showing the absence of a portion of the ridge. *D*, tantalum plate. Note shelving of a portion of the lower border to replace orbital margin.

III. EXTENSIVE DEFECT OF THE CONVEXITY INVOLVING ONE OR BOTH SIDES

Traumatic defects involving one or both sides are for the most part confined to those resulting from war wounds but are occasionally

seen in civilian practice as results of automobile accidents, high velocity missiles, with a bursting type of fracture, and industrial injuries. They are somewhat more frequently seen, however, as results of necessary surgical removal of bone in the treatment of such conditions as acute fulminating osteomyelitis of the frontal region or infiltration of the skull by neoplasms arising either locally or in the adjacent tissues.

The difficulty in obtaining the proper contour of the frontal region depends to some extent on the prominence of the frontal sinuses and the development of the frontal eminences. In these large plates it is particularly important that the amount of curvature be overcorrected to some degree. In fashioning the plate before operation, the impression is made after the defect has been filled in with dental wax. The contour obtained does not allow for the thickness of the soft tissues, and if the convexity is not increased moderately the forehead will appear flat after the plate has been placed. Even in these large plates, it has been the practice to shelve the edge of the bone sufficiently to allow the plate to rest evenly with the surface of the skull.

The exposure must be adequate, and, for these large defects, a concealed coronal incision or unilateral frontal flap passing back of the hair line is usually necessary. The scalp is reflected forward subperiosteally and dissected from the underlying dura. The dead space may be lessened and oozing from the dural surface discouraged by the use of several silk or tantalum wire sutures passed through the dura and fastened to the holes in the plate. It is important that careful hemostasis be obtained to prevent collections of fluid and blood beneath the plate, which might cause extradural compression of the brain. The following 2 cases illustrate the restoration which may be obtained after extensive and highly deforming injuries.

Case 5.—The patient was a soldier admitted to the hospital for repair of a large defect of the frontal and anterior parietal skull secondary to a perforating gunshot wound sustained Feb. 5, 1945. There had been extensive loss of soft tissue at the time of injury, and several plastic procedures were necessary to obtain healing of the wound. At the time of admission there was a large sunken defect, which measured 12 by 12 cm. (fig. 5 *A*). It involved almost the entire frontal region, extending to the superior temporal line on the right and to the midline of the orbit on the left. Superiorly, it reached the coronal suture. The supraorbital ridge was spared on the right, but the upper portion of the ridge was missing on the left.

Prior to operation a large plate was fashioned from an impression taken after the defect had been built up with dental wax. Because of the retained lower portion of the supraorbital ridge on the left, it was not necessary to shelve the lower border of the plate on this side. The defect was exposed through a coronal incision and the scalp reflected forward from the adherent dura. The dead space was reduced by a number of sutures passing from the dura to the holes in the plate. The plate was fastened to the shelved margin of the bone in the usual manner, with several tantalum wedges (fig. 5 *D*).

Postoperatively, there was complete restoration of the frontal contour, with no deformity other than that of the soft tissue scar in the right frontotemporal region at the point of entrance of the missile (fig. 5 *B*).

In the preparation of the plate, the general rule has been to correct the contours and curves prior to operation and to adjust the final size at the time of operation. The plate, when prepared from the impression, is usually made somewhat oversized. Before operation it is fitted to the defect and shaped so as to present no sharp angles or prominences which may serve as points of irritation to the overlying scalp. At this

Fig. 5 (case 5).—*A*, preoperative photograph to show the large, sunken right frontal defect. Note that the major portion of the ridge is spared. *B*, postoperative photograph showing the restoration of the contour of the frontal region. *C*, preoperative roentgenogram showing extent of the defect. Note the presence of tantalum wire sutures at site of dural graft. *D*, postoperative roentgenogram showing the position of tantalum plate.

time, obvious excess of plate is removed and small but important changes are made in the contour. It is frequently necessary to increase the angle between the vertical and the shelving portions of plates for the supraorbital region. In the present case, it was necessary to increase the prominence of the frontal eminences, and this was done with the use of a ball-peen machinist's hammer and a hollowed block of wood. These plus straight and curved dental pliers and heavy

scissors suitable for cutting tantalum sheet metal should be included in the sterile set-up for any cranioplasty with tantalum.

CASE 6.—A soldier was wounded on Jan. 23, 1945, by a shell fragment which entered the right frontal region. There was extensive comminution of the bone and penetration of the dura and brain. After the primary operation, the wound became infected and a draining sinus developed in the left frontal region. On April 20, 1945, a scalp flap was reflected and a large extradural abscess drained. The wound healed without further complication, and repeated roentgenograms of the skull disclosed no evidence of infection of the bone.

There was a large defect, which measured 9 by 8.5 cm. and extended laterally from the midline to include the anterior third of the temporal region (fig. 6 *C*).

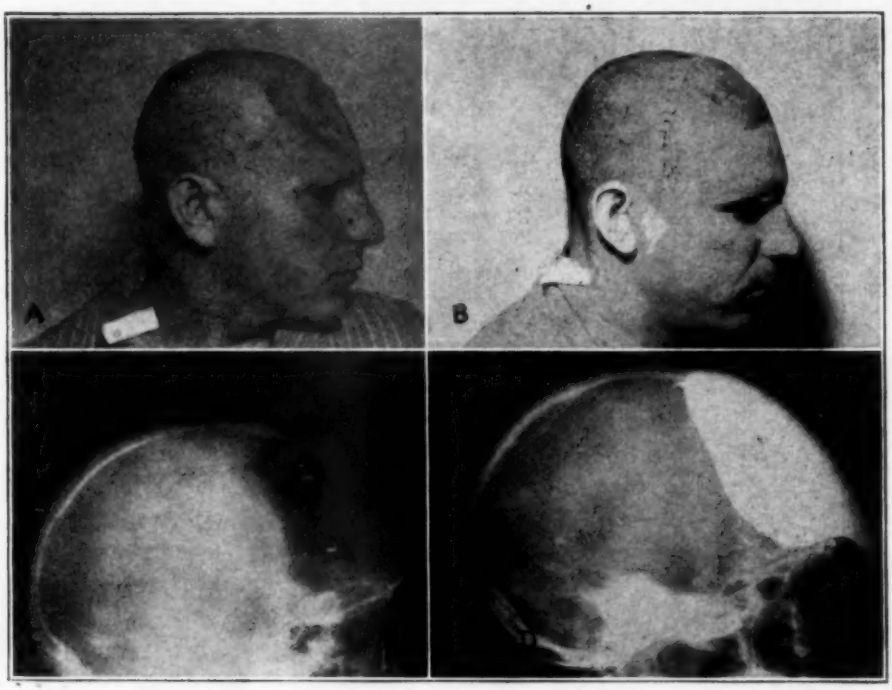

Fig. 6 (case 6).—*A*, preoperative photograph showing extensive bifrontal defect. *B*, postoperative photograph showing restoration of frontal contour and concealed incision. *C*, preoperative roentgenogram showing extent of bone loss. *D*, postoperative roentgenogram showing position of tantalum plate. Note anterior extent of plate to preserve supraorbital contour.

The supraorbital ridge was intact. The defect was sunken, and the scalp seemed adherent to the underlying dura (fig. 6 *A*).

A large plate was fashioned which appeared to reconstruct the contour of the frontal region. The entire defect of the bone was shelved and the plate fastened with tantalum wedges (fig. 6 *B*). Following operation there was some flattening of the forehead, which it seemed desirable to have corrected. Consequently, about six days later the plate was removed and reshaped at the operating table. The subsequent result was one of complete restoration of the normal shape of the head (fig. 6 *B*).

It may be necessary occasionally to remove a plate and adjust the contour if the first operation does not give the maximum cosmetic result. This is a relatively simple procedure, since the time-consuming part of the operation, the dissection of the scalp from the dura and the shelving of the bone edge, has already been carried out. In this case, as in several others, the dura was opened and the site of cortical injury explored. As a rule, prior to cranioplasty all bone fragments retained in the cerebral substance are removed, or where there has been considerable scar formation the scar is excised. It is emphasized that tantalum cranioplasty need not be considered as a separate procedure but can

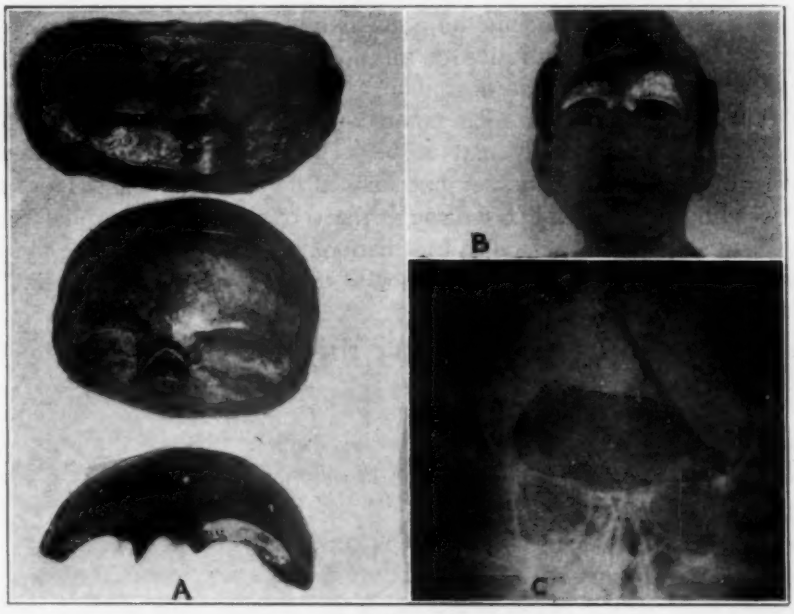

Fig. 7.—*A*, photograph showing metal molds used to form plates with complex curves. *B*, method of fitting plate over defect preoperatively to adjust contour. Note extension from glabella to correct defect of nasal bridge. *C*, roentgenogram showing type of defect requiring restoration of both supraorbital ridges, both orbital plates and bridge of nose.

be carried out as the final stage in any operation which may result in or which involves a disfiguring defect of the skull.

It has been the practice to precede the cranioplasty with a pneumoencephalogram when there is any indication that the underlying cerebral substance has been scarred. Under such conditions, excision of the scar is done and the cranioplasty carried out as an adjunct to this procedure. In several instances distinct improvement in speech defects and subjective symptoms has followed a simple cranioplasty. It is suggested that this is due to relief from the weight and traction of

the sunken and adherent scalp which eventually comes to inhibit the normal pulsations of the brain in the area of the defect.

In the repair of small defects of relatively long standing, it is sometimes necesary to have the plate overlap the edges of the bone for a distance of 1 cm. or more. This is due to the tendency for thinning of the bone edge to occur, and if the usual 2 to 3 mm. ledge for the plate is made in such an instance the entire area of repair will appear somewhat depressed.

SUMMARY

Special consideration has been given to the use of tantalum in the repair of defects of the skull which involve the supraorbital ridge, the orbital rim and plate and the adjacent bony structures. Emphasis has been placed on the restoration of the normal contour of the brow and forehead in relation to the anatomic structure of the supraciliary arch and orbital rim. It has been pointed out that reconstruction of the bony framework not only may serve as the basis for further plastic procedures on the soft tissues but may also prevent the development of unsightly cosmetic defects through the retraction of the orbital contents and soft tissues. Details of formation and adjustment of the tantalum plate to give the maximum cosmetic result have been discussed.

Col. R. Glen Spurling, Medical Corps, Army of the United States, gave suggestions which aided considerably in the preparation of this paper.

CHEMOSURGICAL TREATMENT OF CANCER OF THE NOSE

A Microscopically Controlled Method

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THE term "chemosurgery" was coined to designate a newly developed method for the microscopically controlled excision of certain accessible forms of cancer. The "chemo" portion of the term indicates that the tissues are chemically treated, while the "surgery" portion indicates that the tissues so treated are surgically excised. It is unfortunate, perhaps, that the term omits mention of the thorough microscopic control of excision afforded by the technic, because this control is the most important and only entirely new feature of the method.

The development of the method by experiments on animals [1] and the use of the method in the treatment of various accessible forms of cancer have previously been described.[2] The present article concerns the chemosurgical treatment of cancer of the nose, including the therapeutic results, in a series of two hundred and forty-three lesions treated over a nine year period.

TECHNIC

The chemosurgical technic as applied to the treatment of cancer of the nose will be described by the presentation of the case of the patient pictured in figure 1.

The lesion had begun eight years previously as a crusted ulcer on the lower part of the bridge of the nose, just to the right of the midline. After having been treated three times by means of electrodesiccation and about fifty times by means of roentgen rays over a period of six years, the patient was referred for chemosurgical excision because of continued spread of the basal cell carcinoma. The entire left ala was atrophic, and a hole 3 mm. in diameter entered the nasal cavity in the

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This project was aided by the Thomas E. Brittingham Fund, the Wisconsin Alumni Research Foundation and the Jonathan Bowman Memorial Fund.

From the Department of Surgery, Dr. E. R. Schmidt, chief, State of Wisconsin General Hospital, and the McArdle Memorial Laboratory for Cancer Research.

1. Mohs, F. E., and Guyer, M. F.: Pre-Excisional Fixation of Tissues in the Treatment of Cancer in Rats, Cancer Research **1**:49 (Jan.) 1941.

2. Mohs, F. E.: Chemosurgery: A Microscopically Controlled Method of Cancer Excision, Arch. Surg. **42**:279 (Feb.) 1941; Chemosurgical Treatment of Cancer of the Lip: A Microscopically Controlled Method of Excision, ibid. **48**:478 (June) 1944.

region of the nasofacial sulcus (fig. 1 *A*). There was slight ulceration in the latter region, surrounded by a small amount of visible, pearly, carcinomatous tissue extending onto the ala. Palpation was valueless in detection of the extent of the carcinoma, because the scar tissue and also the fibrocartilaginous structure of the nose were similar to the cancer in consistency.

One-half hour after preparation with 0.03 Gm. of codeine and 0.65 Gm. of acetylsalicylic acid, the portion of the ala which was fairly definitely cancerous was given an application of dichloroacetic acid. When the skin turned white, indicating permeation through the keratin, the first application of zinc chloride fixative Z-108a [3] was made in an even thickness of about 0.5 mm. The fixative was covered with a thin cotton dressing, which in turn was covered by an overlapping cotton dressing spread with petrolatum to form a moisture-tight closure.

Fig. 1.—*A*, basal cell carcinoma of group C (average diameter, 3 to 4 cm.). Starting on the bridge of the nose, it had repeatedly recurred after three electrodesiccations and fifty roentgen ray treatments over a period of eight years. It was excised in six microscopically controlled stages by the chemosurgical technic (see figure 2). *B*, appearance of the lesion after separation of the final layer of fixed tissue. *C*, after healing. The patient had a plastic repair and is free of cancer after six years.

Adhesive tape was accurately applied to hold the dressing firmly in place. The analgesics previously mentioned were prescribed, with instructions to take them as often as every three hours, as needed. The patient was treated as an outpatient.

On the next day a layer of fixed tissue, 1.5 mm. in thickness, was excised with a scalpel. There was no pain or bleeding from this operation because the incisions were made through killed and fixed tissue. Since it was impossible grossly to visualize the cancer in the heavily scarred

3. This fixative paste contains 40 Gm. of stibnite (80 mesh sieve), 10 Gm. of powdered sanguinaria and 34.5 cc. of a saturated solution of zinc chloride.

tissue, the entire area was divided into six specimens so that a systematic microscopic search for the cancer could be carried out. The specimens were mapped on the white, fixed tissue of the lesion (merbromin being used) and on a pad of paper (fig. 2 *A*). The edges of the specimens were marked with merbromin and india ink for orientation (represented by straight and wavy lines respectively on the maps). Frozen sections were cut through the under surface of the specimens, which were examined under the microscope, and the areas of cancer marked on the paper map with red pencil (stippled in the accompanying diagrams). Since

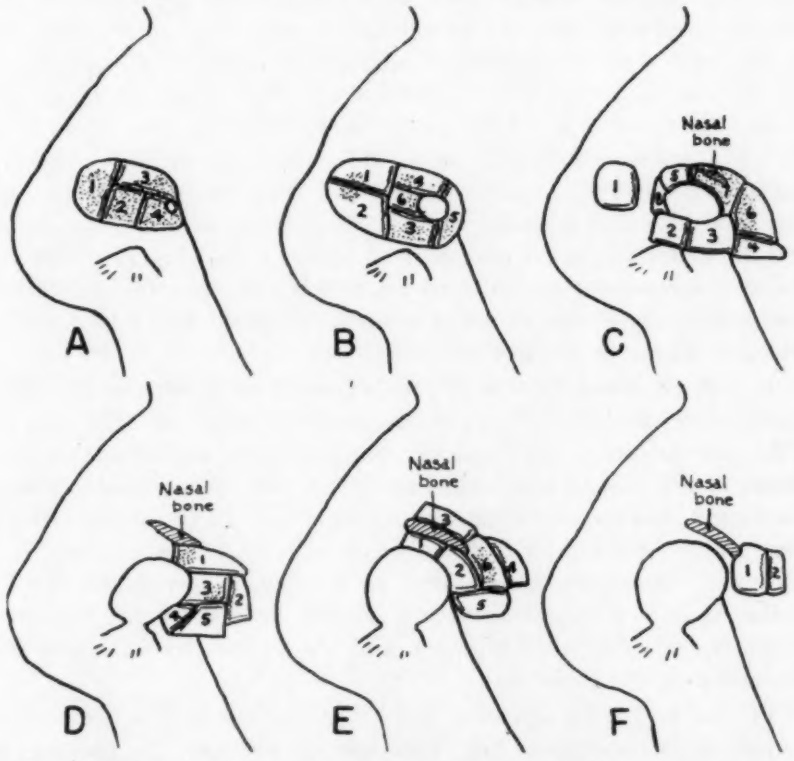

Fig. 2.—Maps showing locations of specimens removed on successive days from the lesion pictured in figure 1. Stippled areas represent cancer located by the microscopic examination of frozen sections made through the under surface of each specimen.

the area proved to be almost completely involved by basal cell carcinoma, the fixative was reapplied to the entire area in a thickness of about 0.5 mm.

The next day a second layer was excised and the areas of cancer located on a map (fig. 2 *B*). Since at this level some cancer-free areas were encountered, the application of fixative was limited to the cancerous portions of the lesion.

The third excision revealed that the remaining cancer was localized to the tissues internal and external to the nasal bone and to the region of the nasofacial junction. Further treatment was confined to these cancerous areas (figs. 2 *C* and 2 *D*), and two days later the tissues on the mucosal and cutaneous sides of the nasal bone became free of cancer (fig. 2 *E*). The last extension, which had eroded rather deeply along the embryologic fusion plane between the nose and the cheek, was eradicated on the following day (fig. 2 *F*).

When a cancer-free plane was reached, the lesion was covered with a petrolatum gauze dressing. Four days after the last application of fixative the remaining thin layer of fixed tissue was loose, so it could easily be removed with sharp-pointed scissors, revealing well vascularized granulation tissue (fig. 1 *B*). (The average time for separation of fixed tissue from the nose is 6.8 days, with limits extending from three to ten days.) The wound then was dressed three times a week with scarlet red gauze. The necrotic portion of the nasal bone was excised one week later, and by one week after that the wound was healed. The patient kept the defect (fig. 1 *C*) covered with adhesive tape, and one year later she was referred for a plastic repair, which was accomplished without complications and with excellent cosmetic results. There has been no evidence of recurrence after six years.

It will be noted that from the beginning of treatment the lesion described required a daily microscopic check on progress. This was due to the fact that the cancer tissue was not grossly distinguishable from the tissues of the nose, which were heavily scarred by previous treatment. Frequently, however, solid masses of cancer may be grossly detected by their grayish white color and cheesy consistency. Where cancer is so evidenced sections are unnecessary, but as soon as any doubt arises as to the nature of tissues sectioning should be instituted. Treatment should not be considered complete until cancer-free sections have been obtained from the entire area.

For lesions on the septum or inside the nose the technic is essentially as previously described, but with special attention to packing for restraining of secretions and holding of the dressings in place. In some instances in which mucous secretion is troublesome, fixative-impregnated gauze may be applied in place of the paste, which would be too rapidly carried away by the secretions. This gauze is prepared by the rubbing of some of the fixative paste into the meshes of cheesecloth and cutting to the desired size.

If bone or cartilage is involved, it is usually grossly evident as treatment proceeds. Fixation and excision are feasible in these tissues as well as in soft tissues except that, in the case of bone, rongeurs and chisels are used in place of the scalpel. Of course, frozen sections of bone cannot be made without the delay of decalcification, but areas of

eroding tissue may be removed and sectioned to determine whether the erosion is due to cancer or other causes.

Hemorrhage was rarely a problem because there are no large vessels in the nasal region. A few patients with hypertension had some bleeding from the angular artery during the separation of the final layer of fixed tissue from around the nasal tip. Though the bleeding usually stops spontaneously within a few minutes, it may be avoided by simply placing a suture-ligature around the vessel, which is located by its pulsation.

THERAPEUTIC RESULTS IN CASES OF BASAL CELL CARCINOMA OF THE NOSE

A total of two hundred and ten basal cell carcinomas of the nose were chemosurgically treated in the nine year period ending May 1, 1945, which date is seven months prior to this writing. The lesions were in all stages, from early to extremely advanced. More than one third of the patients had received unsuccessful surgical or irradiation treatment elsewhere. No instance of metastasis was observed.

End Results After Six Months or More.—While end results after six months are of limited value in comparison of the chemosurgical method with other methods, they come within a few per cent of the ultimate rate of cure. This is so because residual cancer, if left after chemosurgical treatment, usually makes itself evident within a six month period because it is not buried deep in a surgical incision nor is it kept in check by a dense radiation scar.

The 210 cases were divided into "indeterminate" and "determinate" groups, after the example of Martin, MacComb and Blady.[4] The indeterminate group is composed of 8 cases in which the patients died of intercurrent disease without evidence of recurrence or were lost track of without recurrence. The determinate group is made up of 202 cases in which unsuccessful results were obtained (the patients have died of cancer, have been lost from observation with cancer or are living with cancer) and those in which successful results were obtained (the patients who have been free of cancer for six months or more).

In the 202 cases of the determinate group the rate of cure after six months or more was 98 per cent (table 1).

Three Year and Five Year End Results.—An intensive follow-up program had as its aim the observation of every patient for at least five years. Of course, there were a number of deaths before the elapse of that period, due to the preponderance of elderly people in this series. Every effort was made to determine whether or not cancer was present at the time of death. The efficiency of the follow-up system is attested to by the fact that only 5 patients were lost from observation.

4. Martin, H. E.; MacComb, W. S., and Blady, J. V.: Cancer of the Lip, Ann. Surg. **114**:341 (Sept.) 1941.

In the three year period, successful results were obtained in 97.2 per cent of the 109 cases in the determinate group (table 1).

In the five year period, successful results were obtained in 94.3 per cent of the 53 cases in the determinate group (table 1).

TABLE 1.—*End Results for Basal Cell Carcinoma of the Nose After Periods of Six Months, Three Years and Five Years*

This series includes the cases of all patients with histologically proved basal cell carcinomas, both early and advanced, previously untreated and recurrent, who were admitted to the chemosurgery clinic from July 31, 1936 to April 25, 1945 for the six month group; from July 31, 1936 to Oct. 12, 1942 for the three year group, and from July 31, 1936 to Oct. 4, 1940 for the five year group.

	Six Month Period	Three Year Period	Five Year Period
Total number of cases	210	132	80
Indeterminate group			
Patients without recurrence dead from other causes	6	21	24
Patients without recurrence lost from observation	2	2	3
Total number	8	23	27
Determinate group			
Total number	202	109	53
Unsuccessful results			
Patients dead as a result of cancer	4	3	3
Patients with cancer lost from observation	0	0	0
Patients with cancer living	0	0	0
Total number	4	3	3
Successful results			
Patients free from cancer for six month or more	198		
Patients free from cancer for three years or more	...	106	
Patients free from cancer for five years or more	...	...	50
Six month end results			
Total number of cases with successful results divided by total number of determinate cases (198 ÷ 202)	98%		
Three year end results			
Total number of cases with successful results divided by total number of determinate cases (106 ÷ 109)	...	97.2%	
Five year end results			
Total number of cases with successful results divided by total number of determinate cases (50 ÷ 53)	...	...	94.3%

Effect of Size of Lesion on Prognosis.—In the 202 cases in the determinate group in the six month period, the lesions were divided into four groups, according to their average diameter: A, under 1 cm. (fig. 3); B, 1 to 2 cm. (fig. 4); C, 2 to 3 cm. (figs. 1, 5, 6 and 7) and D, 3 cm. or more (figs. 8, 9 and 10).

TABLE 2.—*Effect of Size of Basal Cell Carcinoma on Prognosis*

Group	Average Diameter, Cm.	Number of Lesions	Successful Results	
			Number	Per Cent
A	Under 1	86	86	100
B	1-2	70	70	100
C	2-3	22	22	100
D	3 or more	24	20	83.3
All groups		202	198	98

The end results after a period of six months or more show that there were no failures in groups A, B and C and that the four failures of the entire series were in group D (table 2). As a matter of fact, each of the 4 patients in whom unsuccessful results were obtained had

lost most or all of his nose and had been treated for years by other methods before reporting to the chemosurgery clinic. Treatment in these cases was stopped at an optimum palliative level when it became evident that invasion was so extensive that a repair of the necessary defect would be impractical, in consideration of the age and physical condition of the patients.

It will be noted that even in group D successful results were obtained in 83.3 per cent of the cases. Many of the lesions in this group were

Fig. 3.—*A*, basal cell carcinoma of group A (under 1 cm.). It had recurred after three radium and two electrodesiccation treatments. Microscopic sections revealed a shelflike extension of the neoplasm under the scar superior to the crusted ulcer. The insert shows a reconstruction of the cancer, the actual extent of which was much greater than the small visible portion at the lower end. *B*, healed lesion. The patient is free of cancer after six years.

beyond any reasonable hope of cure by the usual surgical or irradiation technics.

Effect of Previous Treatment on Prognosis.—In the 202 cases in the determinate group in which basal cell carcinomas were chemosur-

TABLE 3.—*Effect of Previous Unsuccessful Treatment of Basal Cell Carcinoma on Prognosis*

	Number of Patients	Successful Results	
		Number	Per Cent
Previously treated	73	69	94.5
Previously untreated	129	129	100

gically excised, seventy-three of the lesions (36.1 per cent) had previously been unsuccessfully treated by surgical operation, roentgen ray, radium or caustics, either alone or in combination. Although it was possible to salvage 69 (94.5 per cent) of these patients, the rate of cure was appreciably below the 100 per cent for the cases in which the patients had not been previously treated (table 3).

The adverse effect of previous treatment on prognosis probably is largely due to the delay occasioned by the ineffective treatment. Some lesions remained healed superficially, and a long time elapsed before the remaining deep-lying cancer made itself evident.

Fig. 4.—*A*, basal cell carcinoma of group B (average diameter, 1 to 2 cm.), located in the nasofacial sulcus. It had repeatedly recurred after electrodesiccation, cauterization, roentgen ray and radium treatments over a period of five years. By the chemosurgical technic it was determined that the full thickness of the ala was cancerous, as was the periosteum of the maxillary bone of the cheek and lateral wall of the nasal cavity. *B*, healed lesion. The patient is free of cancer after four and one-half years.

Fig. 5.—*A*, basal cell carcinoma of group C (average diameter, 2 to 3 cm.). *B*, granulation tissue after the cancer had been removed in four microscopically controlled stages and after the final layer of fixed tissue had separated. *C*, healed lesion. The patient was free of cancer when he died, six years later.

Effect of Histologic Grade of Malignancy on Prognosis.—While there is no formal division of basal cell carcinomas into grades of malignancy, it is practical to designate them as either "invasive" or "non-

invasive." The invasive type is characterized by slender, poorly demarcated carcinoma cells with an indefinite basement membrane between them and the copious connective tissue stroma. The noninvasive type is composed of large, rounded clumps of basal cells, well demarcated by an intact basement membrane from the surrounding relatively meager stroma. Clinically, the invasive type is apt to show the erosion, ulceration and deep induration which is characteristic of the rodent ulcer (illustrated by figures 1, 3, 4, 5, 7, 8, 9 and 10), while the noninvasive type is apt to show the well defined, outgrowing lump characteristic of

Fig. 6.—*A*, basal cell carcinoma of group C. The lesion is of the nodular, outgrowing type, in contrast to the invasive lesions of the other patients herein pictured. *B*, granulation tissue after removal of final layer of fixed tissue. *C*, healed lesion. The patient is free of cancer after five years.

the nodular type of basal cell carcinoma (illustrated by figure 6). Intergradations between these two types are common.

In the 202 cases in the determinate group, 136 (67.3 per cent) were classified as invasive while the remaining 66 were called noninvasive.

TABLE 4.—*Effect of Histologic Grade of Malignancy of Basal Cell Carcinoma on Prognosis*

	Number of Lesions	Successful Results	
		Number	Per Cent
Invasive	136	132	97
Noninvasive	66	66	100

In the invasive group the rate of cure was 97 per cent, while in the noninvasive group successful results were obtained in 100 per cent (table 4).

Keratinization of some degree was observed in 21.3 per cent of the basal cell carcinomas in this series. In many cases there was sufficient keratinization to justify a diagnosis of basal-squamous cell carcinoma,

but separate classification was not deemed desirable, because these lesions behave the same as other basal cell carcinomas except that they are apt to be somewhat more invasive.

One pigmented basal cell carcinoma of the nose was treated by the chemosurgical technic, with a successful outcome.

Effect of Site of Cancer on Prognosis.—In the 202 cases of basal cell carcinoma in the determinate group, sixty-five lesions (32.2 per cent) started on the bridge of the nose, forty-eight (23.8 per cent) on

Fig. 7.—*A*, basal cell carcinoma, group C. It had recurred after sixteen roentgen ray and two radium treatments given over a three year period. *B*, granulation tissue, septal cartilage and nasal bone necessarily exposed due to the deeply invasive cancer. *C*, healed lesion. The small hole into the nasal cavity closed completely after two years. The patient is free of cancer after seven years.

Fig. 8.—*A*, basal cell carcinoma, group D (average diameter, over 3 cm.). *B*, lesion after separation of final layer of fixed tissue showing nasal bone, the periosteum of which had been cancerous, and the unsuspected extent of involvement at the periphery, especially in the right eyebrow. *C*, healed lesion. The patient is free of cancer after seven years.

the tip, forty-three (21.3 per cent) on the ala, twenty-five (12.4 per cent) on the root and twenty-one (10.3 per cent) in the nasofacial sulcus. None were encountered on the nasal septum.

Of the four lesions which failed to respond to chemosurgery, two started on the bridge, one on the tip and one in the nasofacial sulcus

(table 5). However, these lesions were so advanced that little or no nasal tissue remained, and the initial site was determined from the history. The most consistently difficult to eradicate were the lesions beginning in the nasofacial sulcus, because these lesions had a strong tendency to

TABLE 5.—*Effect of Site of Basal Cell Carcinomas on Prognosis*

Site	Number of Lesions	Successful Results	
		Number	Per Cent
Bridge	65	63	96.9
Tip	48	47	97.9
Ala	43	43	100
Root	25	25	100
Nasofacial sulcus	21	20	95.2
Nasal septum	..	..	...
All sites	202	198	98

invade deeply in the embryologic fusion plane in this region. However, the microscopic control of excision afforded by the chemosurgical method made it possible to follow out and eradicate these deep extensions.

Fig. 9.—*A*, basal cell carcinoma, group D, which had started twenty-five years previously in the nasofacial sulcus and had recurred after application of solid carbon dioxide, electrodesiccation and twelve roentgen ray and six radium treatments. *B*, granulation tissue after the cancer had been removed in eight microscopically controlled stages and after most of the final layer of fixed tissue had separated, showing extensive involvement of nose, septum, maxillary bone and upper lip. *C*, healed lesion. The patient was fitted with a latex rubber prosthesis, and he remains free of cancer after four and one-half years.

THERAPEUTIC RESULTS IN CASES OF SQUAMOUS CELL CARCINOMA OF THE NOSE

Squamous cell carcinoma of the nose occurs much less frequently than the basal cell type. Thus, there were only thirty-three squamous cell carcinomas chemosurgically excised in the nine year period ending seven months prior to this writing.

End Results After Six Months, Three Years and Five Years.—The end results were calculated by the same means as were used in the section on basal cell carcinoma. In the six month period, successful results were obtained in 93.9 per cent of the 33 cases in the determinate group (table 6).

In the three year period, successful results were obtained in 87.5 per cent of 16 cases in the determinate group (table 6).

In the five year period, successful results were obtained in 81.8 per cent of 11 cases in the determinate group (table 6).

TABLE 6.—*End Results for Squamous Cell Carcinoma of the Nose After Periods of Six Months, Three Years and Five Years*

This series includes the cases of all patients with histologically proved squamous cell carcinoma, both early and advanced, previously untreated and recurrent, who were admitted to the chemosurgery clinic from July 20, 1936 to Oct. 24, 1944 for the six month group: from July 20, 1936 to July 17, 1942 for the three year group; from July 20, 1936 to July 3, 1940 for the five year group.

	Six Month Period	Three Year Period	Five Year Period
Total number of cases	33	19	12
Indeterminate group			
Patients without recurrence dead from other causes	0	3	1
Patients without recurrence lost from observation	0	0	0
Total number	0	3	1
Determinate group			
Total number	33	16	11
Unsuccessful results			
Patients dead as a result of cancer	2	2	2
Patients with cancer lost from observation	0	0	0
Patients with cancer living	0	0	0
Total number	2	2	2
Successful results			
Patients free from cancer for six months or more	31		
Patients free from cancer for three years or more	..	14	
Patients free from cancer for five years or more	..	..	9
Six month end results			
Total number of cases with successful results divided by total number of determinate cases (31 ÷ 33)	93.9%		
Three year end results			
Total number of cases with successful results divided by total number of determinate cases (14 ÷ 16)	..	87.5%	
Five year end results			
Total number of cases with successful results divided by total number of determinate cases (9 ÷ 11)	..	..	81.8%

Effect of Size of Lesion on Prognosis.—The squamous cell carcinomas were divided into four groups, according to size: A, under 1 cm. in average diameter; B, 1 to 2 cm. (figs. 11 and 12); C, 2 to 3 cm., and D, over 3 cm.

There were only two unsuccessful results in the series: one in size group D and the other in group B (table 7). The former was in a patient with an extremely advanced carcinoma involving, besides the nose, the entire maxillary sinus and the orbit, with an extension of the carcinoma into the brain through the inferior orbital fissure, making it impractical to complete the removal of the neoplasm. The other unsuccessful result was in a patient with a septal lesion which proved to be much more advanced than the original measurement indicated. (Group-

ing as to size is made on the basis of the measurement taken before treatment is started, in order that the results of chemosurgical treatment may be compared with the results of other methods.) The patient was extremely uncooperative, and considerable difficulty was encountered in

TABLE 7.—*Effect of Size of Squamous Cell Carcinoma on Prognosis*

Group	Average Diameter, Cm.	Number of Lesions	Successful Results	
			Number	Per Cent
A	Under 1	8	8	100
B	1-2	17	16	94.1
C	2-3	4	4	100
D	3 or more	4	3	75
All groups		33	31	93.9

keeping the dressings in place. The result was that the fixed tissues became dry and hard, which in turn made it difficult to obtain the usual thorough microscopic control. The patient was referred for roentgen therapy, but eventually metastases developed, causing the patient's death despite surgical dissection of the neck.

Effect of Previous Treatment on Prognosis.—In the 33 cases of squamous cell carcinoma in the determinate group, ten lesions (30.3 per

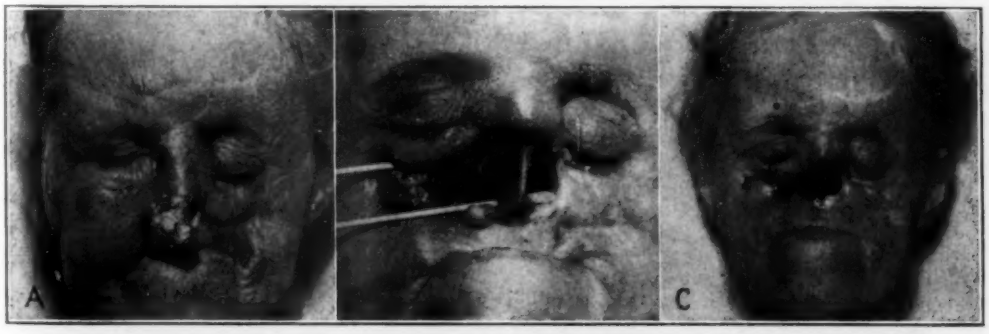

Fig. 10.—*A*, basal cell carcinoma, group D, which had started twenty-three years previously and had failed to heal after competent radium, surgical, radium seed and roentgen ray treatment over a period of twenty-one years. The patient had received no treatment during the last two years of this period because the prognosis was considered hopeless. *B*, lesion after excision of the cancer in twenty-five microscopically controlled stages and after the final layer of fixed tissue separated. Not only was the entire nose cancerous but also involved were the septum (except for the strip in front of the applicator), the turbinates, all the walls of the nasal cavity, the left antrum, the mucosal portion of the upper lip, the anterior half of the hard palate, the periosteum of the right cheek bone and the floor of the right orbit. The orbital portion extended posteriorly to the orbital rim for 2 cm. (where applicator is inserted), but the eyeball was uninvolved, so the vision of this one remaining eye was preserved. *C*, healed lesion (except for the right cheek, from which a piece of necrotic bone had just been removed). The patient is free of cancer after nearly four years and is now undergoing plastic repair.

cent) had recurred after previous unsuccessful treatment by surgical or radiation therapy. Of the 10 patients it was possible to salvage 9 (90 per cent), while of the group of 23 patients whose lesions had not been previously treated 22 (95.6 per cent) were salvaged (table 8).

Effect of Histologic Grade of Malignancy on Prognosis.—Classification of the thirty-three squamous cell cancers of the nose on the basis of Broder's four grades of malignancy revealed a strong correlation

Fig. 11.—*A*, squamous cell carcinoma, group B (average diameter, 1 to 2 cm.). It grew rapidly since its onset two months previously. *B*, granulation tissues after removal of the squamous cell carcinoma in six microscopically controlled stages and after separation of the final layer of fixed tissue. The carcinoma, which was of grade 3 malignancy, extended to within 2 mm. of the nasal mucosa. *C*, healed lesion. There is no evidence of cancer after fourteen months.

Fig. 12.—*A*, squamous cell carcinoma, group B, involving the nasal septum. It had recurred after repeated electrodesiccation and cauterization treatments over a period of three years. *B*, lesion after excision of the cancer in thirteen microscopically controlled stages. The neoplasm had eroded through the upper lip into the gingivolabial sulcus and had involved a large portion of the nasal septum. *C*, healed lesion. The patient is free of cancer after four and one-half years.

between histologic structure and prognosis (table 9). While successful results were obtained in all cases in the grade 1 and grade 2 groups, only 4 of 6 patients in the grade 3 group were successfully treated. There were no cases in the grade 4 group.

Effect of Site of Cancer on Prognosis.—In the 33 cases of squamous cell carcinoma of the nose in the six month period, twelve (36.4 per cent) of the lesions started on the bridge, eight (24.2 per cent) on the ala, five (15.2 per cent) on the tip, six (18.2 per cent) on the septum and two (6 per cent) on the root. None started in the nasofacial sulcus (table 10).

Lesions in all these sites were successfully treated, with the exception of the carcinoma on the ala and the carcinoma on the septum, which lesions were described in the section on the effect of size on prognosis.

TABLE 8.—*Effect of Previous Unsuccessful Treatment of Squamous Cell Cell Carcinoma on Prognosis*

	Number of Patients	Successful Results	
		Number	Per Cent
Previously treated	10	9	90
Previously untreated	23	22	95.6

TABLE 9.—*Effect of Histologic Grade of Malignancy of Squamous Cell Carcinoma on Prognosis*

Grade	Number of Lesions	Successful Results	
		Number	Per Cent
1	10	10	100
2	17	17	100
3	6	4	66.6
4	..	..	...

TABLE 10.—*Effect of Site of Squamous Cell Carcinoma on Prognosis*

Site	Number of Lesions	Successful Results	
		Number	Per Cent
Bridge	12	12	100
Tip	5	5	100
Ala	8	7	87.5
Root	2	2	100
Nasofacial sulcus	..	..	...
Nasal septum	6	5	83.3
All sites	33	31	93.9

Effect of Metastasis on Prognosis.—In only 2 cases of this series did metastases develop. In 1 case the metastasis, which was secondary to a carcinoma replacing the entire nose, was an outlying nodule in a lymphatic vessel near the inner canthus; both primary and secondary lesions were chemosurgically excised, with a successful outcome. The other case was one of unsuccessfully treated carcinoma of the septum previously mentioned; the patient died of metastases after an unsuccess-

ful surgical dissection of the neck. In the first case the carcinoma was large and pendulant, while in the second there was invasion into the upper lip; it is suggested that the movement of the neoplasms as a consequence of these factors may have squeezed cancer cells out into the lymphatics. However, since most cancers of the nose are not subject to motion, metastasis is infrequent in this site.

THERAPEUTIC RESULTS FOR OTHER NEOPLASMS OF THE NOSE

The microscopic control of excision afforded by the chemosurgical method is also advantageous in the treatment of other neoplasms of the nose.

Hemangioma.—One hemangioma in the nasopharynx was successfully removed by a modified chemosurgical technic after surgical and radium treatment had failed, mainly due to profuse hemorrhage. The mass, which was 3 cm. in diameter, was attached to the posterior wall of the nasopharynx. It was treated by the application of small squares of gauze which had been impregnated with the zinc chloride fixative. Since the mass was too far back to admit a scalpel, the fixed tissue was allowed to slough, after which the fixative was reapplied. By treatment of it every third day, the mass was eradicated without hemorrhage. The patient remains well after eight years.

Nevus.—Five nevi, both with and without pigment, were chemosurgically removed from the nose. None are known to have recurred, and in none has melanomatous change occurred after periods of observation of from one month to eight years. Complete removal was assured by the microscopic sections made to determine the depth of the lesion.

Adenoma.—Two sebaceous adenomas and one sweat gland adenoma were chemosurgically removed, with no return after periods of from one to eight years.

Cyst.—Two sebaceous cysts and two epidermoid cysts were successfully removed by chemosurgical measures. Cysts may be treated by cauterizing the central portion with dichloroacetic acid and, after a few minutes, opening the lesion, draining the contents and cauterizing the lining. Microscopic control in the treatment of these lesions is usually not necessary.

THERAPEUTIC RESULTS IN PRECANCEROUS LESIONS OF THE NOSE

Senile Keratosis.—The treatment of senile keratoses depends on the clinical appearance of the lesions. If the lesion is clearly inactive, it is sufficient to pull or scrape off the horny portion of the lesion and then thoroughly cauterize the base with dichloroacetic acid. However, if the lesion is raised, indurated or ulcerated, it is much safer to excise

the lesion chemosurgically and examine it microscopically so that no deep downgrowths of precancerous epithelium are left behind. No instance of recurrence or malignant change is known to have occurred after periods up to nine years in any of thirty-five senile keratoses of the nose treated in this way.

Chronic Ulceration.—There were 2 instances of chronic ulceration, with peripheral epithelial hyperplasia, located on the septum or the floor of the nose. The ulcerations were chemosurgically excised, and healing was uneventful and permanent.

COMMENT

In common with many cancers in accessible sites, cancer of the nose is often characterized by considerable irregularity of shape. That is, in addition to the grossly visible main tumor mass there are often irregular outgrowths of cancer in tissues with reduced resistance to cancer spread, such as periosteum, perichondrium, perineurium, lymphatics and embryologic fusion planes. Most of these outgrowths are not initially demonstrable, even by careful clinical examination, and it is only by the systematic microscopic control attained with the chemosurgical technic that each of these extensions can be accurately followed out and eradicated. This accurate control of excision results not only in unprecedented reliability but also in maximum sparing of uninvolved tissues.

The results here presented adequately indicate the great reliability of the chemosurgical method in the treatment of carcinoma of the nose. For basal cell carcinoma the rates of cure were 98 per cent at six months, 97.2 per cent at three years and 94.3 per cent at five years. For squamous cell carcinoma the rates of cure were 93.9 per cent at six months, 87.5 per cent at three years and 81.8 per cent at five years. These records were attained in spite of the fact that many of the lesions were far advanced and over a third were recurrent after previous unsuccessful irradiation or surgical treatment.

The results obtained by the chemosurgical treatment of carcinoma of the nose compare favorably with those obtained by other methods. One of the few series large enough to use for comparison is that of Magnusson,[5] who reported on the results obtained with the highly developed radiologic, surgical and electrosurgical technics employed at the *Radiumhemmet* in Stockholm. From his protocols it was determined that his three year rate of cure for basal and squamous cell carcinoma of the nose was 92.7 per cent. In the present series the rate of cure obtained by chemosurgery was 96 per cent; this record was attained

5. Magnusson, A. H. W.: Skin Cancer: A Clinical Study with Special Reference to Radium Treatment, Acta radiol. 1935, supp. 22, pp. 1-287.

despite the fact that a higher proportion of my cases were in the groups of the larger-sized lesions (30.4 per cent were in the size groups C and D, as compared with 18.7 per cent in Magnusson's series) and despite the fact that more of my patients had been previously unsuccessfully treated (40.8 per cent in the three year period as compared with 28 per cent in Magnusson's series).

The reliability of the chemosurgical method is not attained by an excessively radical approach. Quite the opposite, not more than 1 or 2 mm. of tissue beyond the actual extent of carcinomatous invasion is destroyed.

The lack of operative risk is a further advantage. In this series, no deaths resulted from chemosurgical treatment, although many of the patients were old and in poor health.

Though the technic entails a considerable amount of hard, tedious work for the far advanced cancers, the great majority of lesions do not require an undue expenditure of time and effort.

SUMMARY AND CONCLUSIONS

The chemosurgical treatment of cancer of the nose has the great advantage of thorough microscopic control of excision. This control is responsible for the unprecedented reliability and the conservatism of the method.

The reliability of the method is indicated by the unusually high proportion of successful results. Thus, for basal cell carcinoma, successful results were obtained in 98 per cent of 202 cases observed for six months or more, in 97.2 per cent of 109 cases in the three year period and in 94.3 per cent of 53 cases in the five year period. For squamous cell carcinoma the rate of cure was 93.9 per cent for the 33 cases in the six month period, 87.5 per cent for the 16 cases in the three year period and 81.8 per cent for the 11 cases in the five year period. These results were obtained despite the fact that many of the cancers were far advanced and over one third had recurred after previous irradiation or surgical treatment.

The method is conservative, since only 1 or 2 mm. of tissue are removed beyond the points of actual carcinomatous invasion.

The method is also useful in the treatment of various benign neoplasms and of precancerous lesions of the nose.

NEW METHOD OF LEG EXERCISES

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AND
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CHICAGO

THE DRAMATIC episode of pulmonary embolism is shocking to the surgeon who suddenly loses his patient in the wake of an apparently uneventful recovery. It is not surprising, therefore, that this tragic event, although of no great frequency, became the topic of numerous investigations dealing with its causes, prevention and treatment.

Three distinct groups of factors can be distinguished in the causation of phlebothrombosis and the resulting embolism: (1) retardation of the venous flow, (2) structural changes in the wall of the affected blood vessels, especially in the endothelium, and (3) changes in the constituents of the blood and chemical changes responsible for coagulation of the blood.

The majority of authors agree that the first-mentioned factor, namely, the retardation of the venous flow, for which lack of muscular contractions is chiefly responsible, is of paramount importance in the genesis of thrombus with resulting embolism. It follows that stimulation of vascular flow should go a long way in the prevention of postoperative pulmonary embolism. In view of the fact that the commonest source of thrombosis leading to embolism is the femoral vein and its tributaries,[1] the lower extremities are receiving the greatest attention in attempts to prevent slowing of the blood stream and associated vascular clotting. Pool[2] suggested a set of active exercises and early ambulation. Various devices have been developed for the same purpose; rollers, against which the patient is instructed to rub his feet and legs[3]; rhythmically contracting air cushions strapped to the patient's legs[4]; levers raising and lowering the patient's limbs[4];

1. Henderson, E. F.: Fatal Pulmonary Embolism, Arch. Surg. **15**:231 (Aug.) 1927. Graves, W. N.: Surg., Gynec. & Obst. **70**:958, 1940.

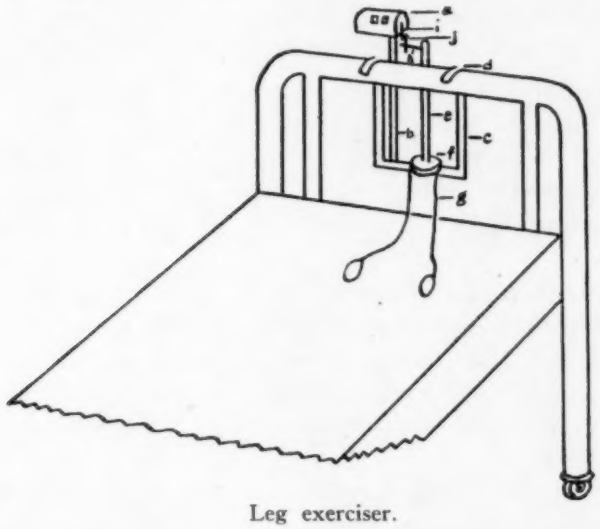
2. Pool, E. H.: Systematic Exercises in Postoperative Treatment, J. A. M. A. **60**:1202 (April 19) 1913.

3. Shaw, W. F., and Rickards, C. E. B.: J. Obst. & Gynaec. Brit. Emp. **45**:451, 1938.

4. Robertson, H.: Am. J. Surg. **41**:3, 1938.

pedaling apparatus,[5] and a device consisting of a stand which carries two pulleys with counterbalance weights.[6]

The efficiency of postoperative exercises in prevention of pulmonary embolism is attested by Erskine and Shires,[7] who reported that the incidence of fatal embolism after abdominal operations was reduced by more than half following the introduction of postoperative exercises



Leg exerciser.

and massage. Fletcher Shaw and Rickards[3] found fatal embolism to be five times commoner in a hospital where exercises are not included in the postoperative treatment as compared with another institution where exercises are carried out as a routine.

On the other hand, certain disadvantages of the aforementioned devices should be mentioned: Most of them are bulky and cumbersome; either they take considerable space in the bed, affecting the patient's comfort, or they protrude from the bed, interfering with a free passage in the room; patients must be uncovered to perform the exercises; some devices are impractical or expensive; they are time consuming because they require supervision, and, finally, they provide no facilities for registration, which is essential because pain or lack of interest caused by sedation may prevent the patient from faithfully exercising his legs.

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5. Gamble, H. A.: Am. J. Surg. **28**:93, 1935. Cogswell, H. D., and Thomas, C. A.: Surgery **10**:323, 1941.

6. Gambill, I. M., and Kamenshine, A.: M. Bull. Vet. Admin. **20**:173, 1943.

7. Erskine, J. P., and Shires, I. C.: J. Obst. & Gynaec. Brit. Emp. **52**:480, 1945.

To overcome such drawbacks, the authors developed an apparatus which is inexpensive, simple in construction, takes practically no space, allows the patient to remain covered and permits registration of the movements of the legs. Such a device saves valuable time of the understaffed nursing personnel, induces the patient to carry out the instructions and offers an easy way for a check-up. The exercises can be graded, increasing in number with the progress in the patient's condition.

DESCRIPTION OF THE APPARATUS

The apparatus consists essentially of a counting machine (*a*) mounted on a bracket (*b*) of an aluminum U-frame (*c*) whose both ends are hook shaped (*d*) so that they can be hung over the foot of the bed. A vertical shaft (*e*) which rises from the center of the transverse portion of the frame supports a pulley (*f*). Both looped ends of a sash cord (*g*) which rides around the pulley are attached to the patient's feet. A horizontal rod (*h*) attached to the top end of the vertical shaft trips the arm lever (*i*) of the counter whenever the pulley rotates. The lever is equipped with a hinged end piece (*j*), which permits tripping of the lever only in one direction.

SUMMARY

A new device for exercising the legs is described, which offers the following advantages in comparison with similar devices: 1. It has a simple construction and can be attached to the foot of the bed without any screws or clamps. 2. It is compact. 3. It can be used without uncovering the patient. 4. It is inexpensive. 5. It is provided with a counting machine, which permits graded exercises without supervision by the nursing personnel.

1200 North Ashland Avenue.

REACTION OF TISSUE TO AND THE FATE OF OXIDIZED CELLULOSE IN THE PERITONEAL CAVITY OF THE DOG

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FOREIGN substances which can be left in tissues have been used for some time in various fields of surgery. Relatively nonirritating materials, such as metal plates, screws and wire, have been used in the open reduction of fractures, but these rarely cause trouble unless infection is present.

Silk, cotton and nylon used for ligature are usually introduced in such small amounts that they become clothed in varying amounts of fibrous tissue and lead to no further trouble. Surgical gut, though more irritating to the tissues, is completely absorbed. Large amounts of gauze, usually in the form of sponges, accidentally left in the tissues usually result in some complicating reaction sooner or later.

Gauze packs are used sometimes to promote adhesions and, when they have accomplished this purpose, are removed with impunity. However, there are occasions when such packs are used for purposes of hemostasis, but their removal may initiate fresh bleeding. Then, too, infection may easily be introduced in such a wound, and a gauze pack not only inhibits drainage but may obscure such infection.

Therefore, a gauzelike material which can be left in tissues and which causes no untoward reaction therein is highly desirable.

Cellulose is the term applied to a class of compounds which, in common with starch and glycogen, may be designated by the empiric formula $(C_6 H_{10} O_5)_x$ and classified as hexosans or glucosans. On complete hydrolysis, cellulose from any source yields glucose. Cellulose occurs in the fibrous or supporting tissues of plants and in the walls of plant cells. It occurs in relatively pure form in cotton.[1]

Oxidized, or absorbable, cellulose has been prepared by Kenyon [2] and associates. The cellulose was oxidized by the action of nitrogen

From the Department of Surgery, St. Louis University School of Medicine.
The material with which this work was done was supplied by Parke, Davis & Company, Detroit.

1. Bodansky, M.: Introduction to Physiologic Chemistry, ed. 3, New York, John Wiley & Sons, Inc., 1934.

2. (*a*) Unruh, C. O., and Kenyon, W. O.: Investigation of the Properties of Cellulose Oxidized by Nitrogen Dioxide, J. Am. Chem. Soc. **64**:127, 1942. (*b*) Yackel, E. C., and Kenyon, W. O.: The Oxidation of Cellulose by Nitrogen Dioxide, J. Am. Chem. Soc. **64**:121, 1942.

dioxide on it in a closed chamber. The cellulose was then air dried after having been washed with distilled water. There was no shrinkage in amount. Depending on the amount of oxidation, oxidized cellulose with various contents of carboxyl (COOH) groups are obtained. Oxidized celluloses, having contents of carboxyl groups up to 15 per cent are fluffy white materials, which cannot be distinguished from the original cellulose by visual examination and are not friable and the fibers of which do not break up when handled. Materials having carboxyl contents greater than 15 per cent maintain their fibrous structure, but there is some shrinkage, accompanied with surface hardening.

Alkali solubility (usually 10 per cent sodium hydroxide) is employed as a test of the oxidation of cellulose. The products of mild oxidation are usually only partially soluble, while those of vigorous oxidation dissolve completely. Celluloses whose content of carboxyl groups is above 13 per cent dissolve in dilute aqueous solutions of inorganic or organic bases, while celluloses with less than 13 per cent content of carboxyl groups do not dissolve.

Seegers and Doub [3] found that oxidized cellulose contains approximately 20 per cent of carboxyl groups.

Oxidized cellulose in the form of gauze is sterilized with solution of formaldehyde, which does not leave a trace of formaldehyde sufficient to render the material irritating. It is then doubly packaged in individual sterile envelopes. It cannot be reautoclaved, since it disintegrates, but may be boiled three minutes or kept in 70 per cent alcohol until used.[4]

The gauze is 3 inches (7.5 cm.) square, and the thickness is 8 ply. It is white, with a slight yellow tinge, and is somewhat more friable than ordinary gauze.

Heidelberger and Hobby [5] have shown that oxidized cellulose contains an immunologically specific polysaccharide.

Experiments were carried out in which oxidized cellulose was placed in the peritoneal cavities of dogs and the effect observed.

The animals used were ordinary mongrel dogs of various sizes and weights and of both sexes. Intravenous injections of pentobarbital sodium were used for anesthesia, and the operation was done under sterile conditions, a right rectus incision being used. In every case the peritoneal cavity was uninfected.

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3. Seegers, W. H., and Doub, L.: Oxidized Cellulose and Thrombin, Proc. Soc. Exper. Biol. & Med. **56**:72, 1944.

4. Uihlein, A.; Clagett, O. T.; Osterberg, A. E., and Bennett, W. A.: Absorbable Oxidized Cellulose with Thrombin as a Hemostatic Agent in Surgical Procedures, Surg., Gynec. & Obst. **80**:470, 1945.

5. Heidelberger, M., and Hobby, G.: Oxidized Cotton: An Immunologically Specific Polysaccharide, Proc. Nat. Acad. Sc. **28**:516, 1942.

TABLE 1.—*Oxidized Gauze 2 x 1 cm. (8 Ply)*

Dog	Time, Days	Gross Appearance of Gauze: Between Liver and Diaphragm	Among Intestines	In Pelvis	In Omental Bursa	Microscopic Appearance of Gauze
1	1	Small brown mass	Gelatinous mass	Gelatinous mass	Brown gelatinous mass	There is a moderate inflammatory reaction, characterized by neutrophilic infiltration and congestion of blood vessels; surrounding tissue intensely inflamed
2	2	Brownish gelatinous mass	Brownish spot	Absorbed	Dark brownish gelatinous mass	There is a more pronounced neutrophilic infiltration of the gauze; otherwise the reaction is the same as that seen in the above section
3	3	Absorbed	Absorbed	Absorbed	Semiliquid, brownish gelatinous mass	The inflammatory reaction is less intense, but in addition to the neutrophilic infiltration of the fibers, there are many macrophages present; these are relatively large and round, with clear, slightly basophilic cytoplasm
4	4	Absorbed	Absorbed	Absorbed	Approximately one-half original size; gelatinous; semisolid	There is beginning disintegration of the gauze fibers, and fibroblasts are seen in the inflammatory exudate surrounding the gauze and its individual fibers
11	8	Absorbed	Absorbed	Absorbed	No evidence of gauze found	No section made
13	11	Absorbed	Absorbed	Absorbed	Approximately one-half original size; brownish fibers	There is still an intense inflammatory reaction in the tissue surrounding the gauze; the gauze is infiltrated by large numbers of the macrophages mentioned, with a more complete disintegration of the gauze
8	17	Absorbed	Absorbed	Absorbed	Few dark brownish fibers	Few gauze fibers are seen; many macrophages are still present, but in addition many more fibroblasts are seen
5	21	Absorbed	Absorbed	Absorbed	Small brownish spot	Only a few gauze fibers are seen; these are almost completely disintegrated and are surrounded by large numbers of macrophages, whose cytoplasm is filled with dark granular brownish-staining materials
7	28	Absorbed	Absorbed	Absorbed	Small brownish spot	No section made
9	28	Absorbed	Absorbed	Absorbed	Small brownish spot	No section made
10	28	Brown spot	Absorbed	Absorbed	Tannish stain	One small gauze fiber is seen, surrounded by macrophages, fibroblasts, fibrocytes and a few neutrophils

In the first group of animals, pieces of cellulose in the form of gauze were placed in various positions in the peritoneal cavities. The gauze measured 2 by 1 cm., and the thickness was 8 ply. Such pieces of gauze were placed as follows: (*a*) in the omental bursa, (*b*) between the right side of the diaphragm and the liver, (*c*) among the intestines, (*d*) in the pelvis. Only gauze was introduced into the peritoneal cavity, as it was not desired that sutures to hold the gauze in place or for purposes of marking should be present possibly to influence the reaction.

The peritoneal cavities of the animals were reopened, each at a different time, until such time as the gauze was absorbed, and sections from omental bursa were taken for microscopic study.

Fig. 1.—Appearance of the gauze in the omental bursa after three days.

Table 1 summarizes the results obtained with this group.

Macroscopically, the gauze forms a gelatinous brownish mass, which primarily is larger than the original mass of the gauze but gradually decreases in size as it is completely absorbed. Figure 1 illustrates the appearance of the gauze placed in the omental bursa after three days.

Microscopically, there is in the early stages a moderate acute inflammatory reaction, with many neutrophils present. Fibroblasts are seen

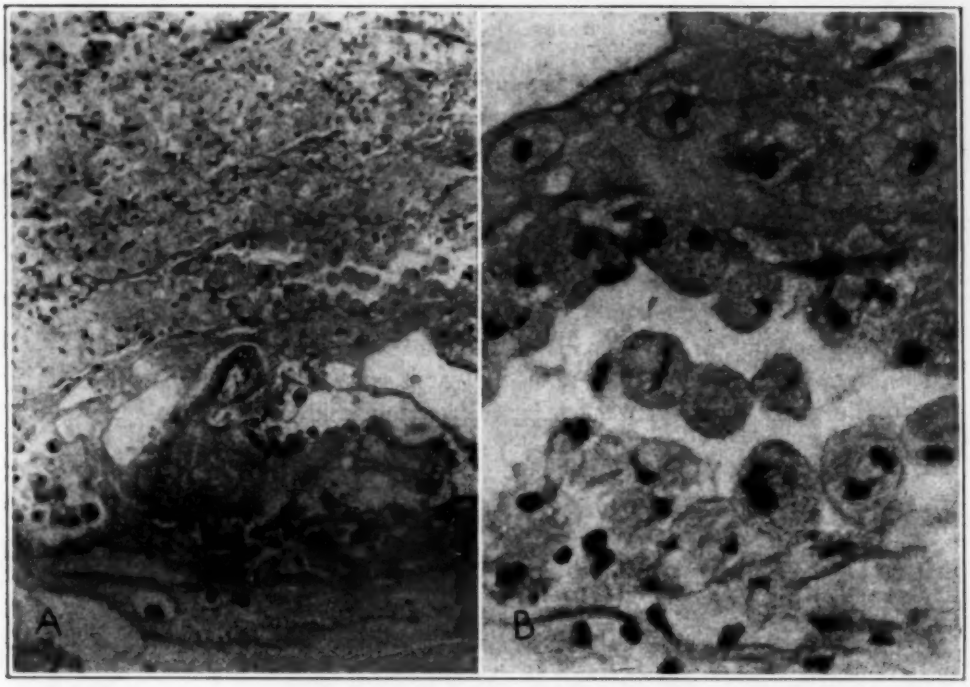

Fig. 2.—Large rounded macrophages with basophilic-staining granules in the cytoplasm after eleven days. *A*, × 10; *B*, × 44.

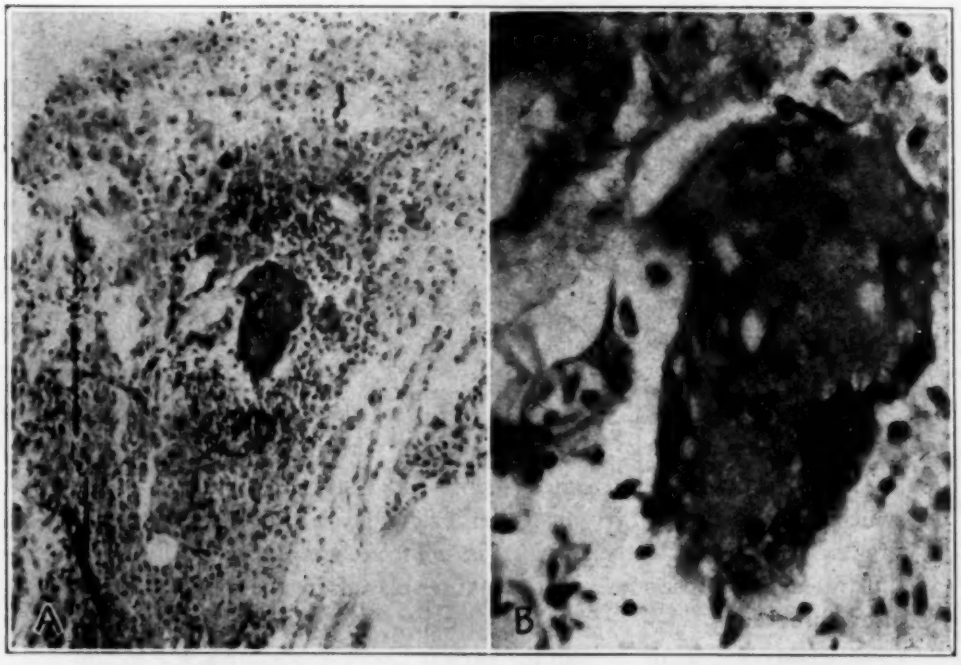

Fig. 3.—*A*, moderate number of macrophages and neutrophils are present, surrounding the one gauze fiber seen in the center of the photograph. There are also numerous fibroblasts (× 10). *B*, infiltration of the fiber by the cellular exudate (× 44).

in the inflammatory exudate on the fourth day, and on the eleventh day large numbers of macrophages are seen around the gauze. The latter cause a further disintegration of the gauze, the fibers gradually decreasing in size until complete disappearance.

The photomicrographs illustrate some of the features mentioned.

Figure 2 (*A*, × 10 and *B*, × 44) shows the presence of large numbers of large rounded macrophages, with slightly basophilic-staining granules in the cytoplasm after eleven days.

Figure 3 (*A*, × 10 and *B*, × 44) shows the appearance of the gauze after seventeen days. One gauze fiber is seen in the center of the photograph. A moderate number of macrophages and neutrophils are present surrounding the gauze, but in addition there are numerous fibroblasts. Figure 3 *B* demonstrates infiltration of the fiber by the cellular exudate.

TABLE 2.—*Oxidized Gauze 4 x 2 cm. (8 Ply)*

Dog	Time, Days	Gross Appearance of Gauze
14	10	Tiny brownish spot found on serosal surface of small intestine
16	10	One small brownish fiber found adherent to serosal surface of small intestine; no adhesions formed
18	10	No trace of any gauze found; no adhesions formed

TABLE 3.—*Oxidized Gauze 4 x 4 cm. (8 Ply)*

Dog	Time, Days	Gross Appearance of Gauze
15	14	Small brownish fiber found approximately 4 x 1 mm., adherent to mesentery of small intestine; no adhesions formed
17	13	No gauze found; no adhesions formed
19	14	No gauze found; no adhesions formed

In the second and third groups (tables 2 and 3 respectively), the gauze was placed between loops of small intestine.

CONCLUSIONS

Oxidized gauze is completely absorbed in the peritoneal cavity of the dog. A brownish gelatinous mass is formed, which gradually decreases in size until it is finally absorbed.

A piece of oxidized gauze 2 by 1 cm. (8 ply) is completely absorbed in the omental bursa of the dog in approximately twenty-eight days. A piece of the size described when placed among the intestines is completely absorbed in two days. A piece of oxidized gauze 4 x 2 cm. (8 ply) when placed among the intestines is completely absorbed in approximately ten days, while a piece 4 by 4 cm. (8 ply) similarly placed is completely absorbed in approximately thirteen days.

In some cases, during the process of absorption fibrinous adhesions are formed, but after complete absorption no adhesions are formed and there is no visible trace of the gauze.

Systemic changes, i. e., fever, leukocytosis, increase in pulse rate and increase in sedimentation rate, were not recorded, because there was no adverse systemic clinical condition observed.

The absorption of the gauze may, in part at least, be due to solution by the tissue juices,[6] but a large part of the absorption is definitely due to digestion by macrophages.[7]

The variability of the time for absorption may be due to the amount of the gauze present, the degree of oxidation of the gauze (products with less than about 13 per cent of carboxyl groups do not dissolve),[2b] uniformity of the oxidation of the gauze, the nature of the tissue, the amount and type of peritoneal fluid present and the mechanical motility of the surrounding tissues (in this case, abdominal viscera).

It occurred to me that oxidized cellulose might well be used as an effective substitute when the use of a gauze pack is deemed necessary. It may also be used for hemostasis,[8] either by itself or in combination with some blood derivatives such as thrombin, but I made no effort to verify these suppositions by tests, because they were not within the province of this thesis.

SUMMARY

1. Oxidized cellulose forms a brownish gelatinous mass, which gradually decreases in size until it is completely absorbed in the peritoneal cavity of the dog.

2. The rate of absorption depends on the amount of gauze (cellulose) present.

3. No intraperitoneal adhesions are formed after complete absorption of the gauze.

4. The absorption is due in a large part to phagocytosis.

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6. Frantz, V. K.: Absorbable Cotton, Paper and Gauze (Oxidized Cellulose), Ann. Surg. **118**:116, 1943.

7. Lattes, R., and Frantz, V. K.: Absorbable Sponge Tests, Ann. Surg. **121**: 894, 1945.

8. Frantz, V. K.; Clarke, H. T., and Lattes, R.: Hemostasis with Absorbable Gauze (Oxidized Cellulose), Ann. Surg. **120**:181, 1944. Frantz, V. K., and Lattes, R.: Oxidized Cellulose Absorbable Gauze, J. A. M. A. **129**:798 (Nov. 17) 1945.

NONTRAUMATIC SPONTANEOUS RUPTURE OF THE SPLEEN

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NONTRAUMATIC spontaneous rupture of an apparently normal spleen, considered by some as an impossibility, is indeed a rarity. Ask-Upmark [1] studied a total of 120 cases of rupture of the spleen, and it included only 2 cases in which the history was absolutely negative regarding trauma. One of the cases concerned a 43 year old man in whom the ruptured spleen was macroscopically normal. No microscopic examination was made. The other case was that of a 30 year old man. The ruptured spleen weighed 250 Gm., and it contained no coagula. The microscopic examination showed hyalinization of the arterioles and increase of stroma. Ask-Upmark concluded that a spontaneous rupture of a normal spleen is possible, explaining it on a basis of a functional lienal apoplexy.

Zuckerman and Jacobi [2] reported a case of genuine spontaneous rupture of a normal spleen in a 29 year old woman, with a report of the autopsy. Reviewing some 28 cases, 21 genuine and 7 dubious, they concluded that there exist cases of genuine nontraumatic spontaneous splenic rupture. In their case, the spleen, removed at autopsy, measured 17 by 9.5 by 5 cm. and weighed 385 Gm. Microscopic examination of the spleen showed all the sinuses extremely distended, with masses of well preserved erythrocytes in large numbers. No other changes were noted. Microscopic examination of the other organs showed only severe anemia.

Dahle [3] found 14 cases in the literature in which trauma could positively be excluded; yet rupture of entirely normal spleens occurred.

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1. Ask-Upmark, E.: On the Question of the Pathogenesis of So-Called Spontaneous Ruptures of the Spleen, with Some Remarks on the Symptomatology, Klin. Wchnschr. **16**:897 (June 19) 1937.

2. Zuckerman, I. C., and Jacobi, M.: Spontaneous Rupture of the Normal Spleen, Arch. Surg. **34**:917 (May) 1937.

3. Dahle, M.: Rupture of Normal Spleen Without Known Cause: Spontaneous Rupture, Acta chir. Scandinav. **75**:519, 1934.

His case was that of an 18 year old boy, and the surgically removed spleen, with recovery of the patient, was normal macroscopically and microscopically.

Shafir,[4] reviewing the literature, found 34 cases and added 1 of his own. He concluded that rupture of the macroscopically and microscopically normal spleen is a rarity but does occur. Müller [5] reported 1 case and concluded similarly.

On the other hand, Lundell [6] found 20 cases in the literature which were designated as spontaneous rupture of a healthy spleen either by the authors themselves or by other authors. Subjecting these to a critical evaluation, Lundell did not find a single case in which it was clearly demonstrated that a healthy spleen may rupture spontaneously.

Rubnitz [7] stated that "A normal spleen will not rupture unless it is subjected to violence of a considerable degree. Rupture of the spleen in the absence of obvious trauma is an indication that deep-seated degenerative and necrotic changes have taken place."

REPORT OF A CASE

History.—W. W., a white man aged 46, an inspector of rubber goods, was seen by one of us (I. S.) on Sunday April 8, 1945, about 4 p. m., while he was in a state of semishock. The history given was that the patient had enjoyed normal good health up to a few hours before. He had been working regularly an eight hour day shift six days a week until Saturday, April 7, at 3 p. m. On Sunday, between 8 and 10 a. m., he partook of ham, eggs, coffee and similar food. At 12 noon he ate his usual Sunday dinner. At 1:30 p. m., while out in the back yard relaxing, he was seized suddenly with violent and excruciating pain in the lower part of the abdomen. Usual household remedies such as enema, ice bag and sodium bicarbonate failed to give relief. His condition became worse.

The patient was absolutely certain that he had not injured any part of his body. He never had any symptom referable to the gastrointestinal system, he never suffered from malaria or typhoid fever and he had never been out of the state of New Jersey, his birthplace. He had had lobar pneumonia in 1925. There had been no recent loss of weight. The patient drank an occasional glass of beer and smoked moderately. He had enjoyed normal health for the past twenty years, up to his recent illness. These facts were obtained time and again, with no variation.

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4. Shafir, L.: Spontaneous Rupture of Normal Spleen, Vestnik khir. **60**:574, 1940.

5. Müller, J. X.: Spontaneous Hemorrhages of the Spleen, Chirurg **12**:265 (May 1) 1940.

6. Lundell, G.: Spontaneous Rupture of the Spleen, Acta chir. Scandinav. **75**:547, 1934.

7. Rubnitz, A. S.: Spontaneous Rupture of the Spleen Due to Acute Leukemia or Acute Leukemia Due to Trauma to Spleen—Which? J. Lab. & Clin. Med. **28**:972 (May) 1943.

Physical Examination.—The patient was restless, tossing from side to side, with beads of cold, clammy perspiration on his drawn pale face. His lips were dry. The pulse rate was 120 and the respiratory rate 24 per minute. His temperature was 98.0 (37.7 C.) per mouth. The examination of the chest exhibited no pathologic changes. The abdomen, somewhat distended, was difficult to palpate because the patient assumed a voluntary rigidity of the abdominal muscles and with his hands warded off the examiner's palpating hand. A diagnosis of a ruptured abdominal organ was made and immediate hospitalization insisted on.

Course and Treatment.—The patient arrived at the Passaic General Hospital at 5 p. m., April 8. He no longer complained of pain, was comfortable and needed no relief. Morphine sulfate, ¼ grain (0.015 Gm.), was given, nevertheless; at 6:45 p. m. the patient was seen in consultation with the surgeon (A. P. R.), who concurred in the diagnosis of a ruptured abdominal organ, and operation was decided on.

Operation.—At 8 p. m., with the patient under general anesthesia, a midline epigastric incision was made. An estimated 1,000 to 1,200 cc. of fresh blood was found in the peritoneal cavity. About 600 cc. of that was filtered and infused intravenously while the patient was still on the operating table. The spleen was found to have a deep tear in the anterior midportion; the splenic hilus was clamped through a left-sided oblique incision, commencing below the upper angle of the midline incision and proceeding at a 45 degree angle to it laterally for a distance of 4 to 5 inches (10 to 12.5 cm.). A normal-sized spleen was removed. Both incisions were closed in layers. A rubber drain was inserted in the midline incision, and the patient returned to his room, in poor condition.

Postoperative Course.—Continuous infusions of 5 per cent dextrose in isotonic solution of sodium chloride were given for forty-eight hours. On the third day an additional 500 cc. of blood was administered, and on the fourth postoperative day the condition of the patient was greatly improved and the temperature was down to 99 F. On the eleventh postoperative day, a sudden rise to 102.6 F. (39.2 C.) was observed. No cause could be found. A roentgenogram of the chest exhibited no pathologic changes, and penicillin, 600,000 units, was administered intramuscularly to the fourteenth day, when the temperature became normal. Both wounds healed without complications, and on the eighteenth postoperative day the patient was discharged from the hospital.

He continued to gain strength and weight, and on June 1 he insisted on returning to work.

Future Course.—He was last examined in the presence of Dr. M. Wachstein, pathologist at Beth Israel Hospital, at that institution on June 30, 1945, when a total blood count and count and smear of bone marrow and material obtained by sternal puncture were made. At that time, the patient stated that he had regained the 14 pounds (6.4 Kg.) that he had lost while hospitalized and had gained an additional 10 pounds (4.5 Kg.). He was entirely recovered.

Laboratory Report.—The spleen measured 12 by 10 by 7 cm., it weighed 225 Gm. and it was dark reddish purple and was slightly friable. It contained a large linear lacerated area, measuring 5.8 cm. in length and situated in its anterior midportion. The areas in the vicinity of laceration were infiltrated with extravasated blood. The splenic capsule was moderately stretched and slightly thinned. On its outer surfaces fibrous trabeculae were clearly demarcated. The malpighian

follicles were slightly obliterated in the vicinity of extravasated blood. The splenic pulp was softened in the area affected by the hemorrhage. No microscopic sections were made.

Several routine urinary analyses gave normal results. Blood counts following the operation were as follows:

	4/9/45 2d Post-operative Day	4/19/45 11th Post-operative Day	4/23/45 15th Post-operative Day	6/30/45
Total red cells	3,200,000	3,400,000	4,000,000	4,320,000
Hemoglobin	67%	69%	75%	81%
Total white cells	17,500	32,200	7,200	9,000
Polymorphonuclears	89%	82%	69%	48%
Lymphocytes	8%	12%	25%	48%

The bone marrow count revealed 70,500 cells per cubic millimeter, and the smear was normal except for 25 per cent lymphocytes. The normal is 10 per cent and the high normal 15 per cent.

COMMENT

A review of the literature shows that not in a single instance of spontaneous rupture of the spleen was an absolutely correct diagnosis made preoperatively or ante mortem. No single diagnostic sign, not even shock, occurred in all the cases. The site of rupture also was extremely variable, the two surfaces, the upper and lower poles, and the hilus and notch being equal favorites.

Sex and age played no part. The literature is silent on subsequent examinations of bone marrow or blood count. A hematologic study in our case revealed that while the total white cell count remained normal the lymphocyte count gradually increased from 8 to 48 per cent. Attention is invited to the bone marrow count and its 25 per cent lymphocytes, which is much higher than normal.

SUMMARY

A 46 year old white man, in previous good health, sustained a nontraumatic rupture of a grossly normal spleen. Splenectomy was performed within six and one-half hours after the onset of his illness. He made an uneventful recovery and was alive and well some fourteen months after the operation.